POWER PLANT ENGINEERING

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Kosmos Ice Plant Is Electrically Operated

RAW WATER ICE PLANT INSTALLS WATER SOFTENING SYSTEM TO REDUCE CORE PUMPING COSTS

HAVING SPENT a portion of the winter season in making a few alterations in design and all necessary repairs, the Kosmos Ice Co., operating a 200-T. plant at 58th and Halsted Sts., Chicago, is now engaged in building up its 5000-T. reserve to carry over the peak demands that will be encountered during the coming summer. The alteration in design consisted in installing water softening equipment for the purpose of producing a better quality of ice and of reducing the cost of pumping cores. The repairs involved reboring the cylinders of the three larger compressors, fitting new pistons and turning down the piston rods; and cleaning the brine tanks, brine coolers and the condenser. In addition to this, the whole plant was given a general house-cleaning, all equipment was subjected to a thorough inspection and all exposed iron surfaces were painted. The whole plant now shines like new and it is expected that it will perform accordingly.

This plant manufactures raw water ice and is electrically driven throughout, the only boiler being a small unit that is used to heat the water in the dip tanks and to heat certain portions of the building during the winter. Briefly, the arrangement is this: across the narrow dimension of the building and along the street frontage is the compressor room where, besides the compressors, the circulating pumps and air compressors are located. Back of this is the tank room in which there are three tanks of equal capacity. Immediately back of this is the smaller storage room and beside it a

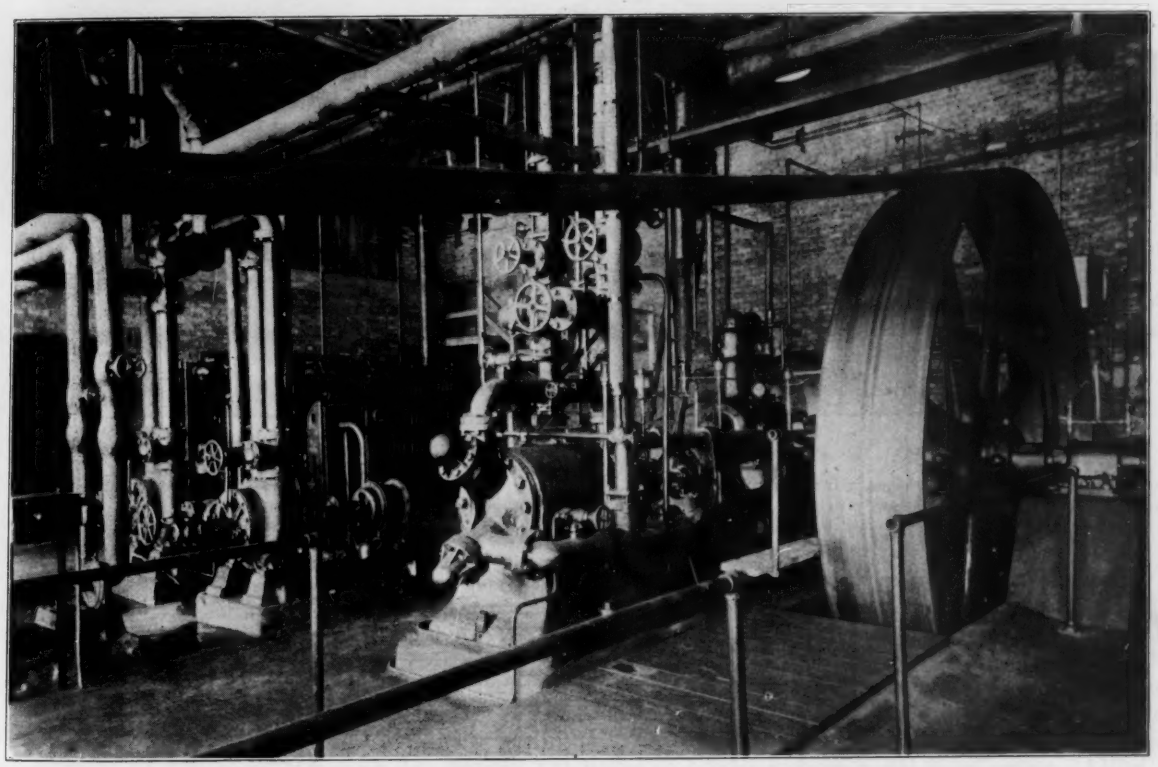


FIG. 1. HORIZONTAL, SINGLE CYLINDER, DOUBLE ACTING AMMONIA COMPRESSOR AT THE PLANT OF THE KOSMOS ICE CO.

long and narrow storage space of somewhat greater capacity. Above the small storage on the roof is the condenser and cooling tower. A graphical impression of this layout may be obtained by referring to Fig. 2, which shows a plan of the building.

Compressors

In the compressor room, there are four ammonia compressors having a total capacity of 225 T. which, for the purpose of identification, may be numbered 1, 2, 3 and 4. The first three units are Triumph Ice Machine Co. horizontal, single-cylinder, double-acting compressors, belt driven from synchronous motors, and the fourth is a vertical, two-cylinder, single-acting, York compressor belt driven from an induction motor.

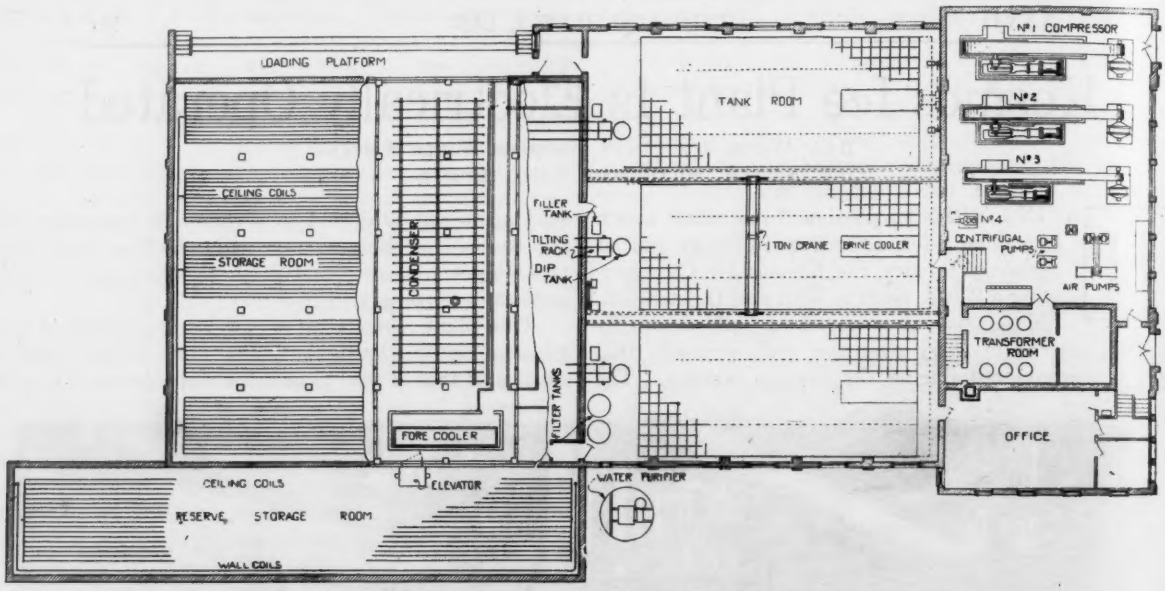


FIG. 2. PLAN OF BUILDING SHOWING GENERAL ARRANGEMENT OF UNITS

Number 1 machine, a section of which is shown in Fig. 3, has a rated capacity of 80 T. The cylinder is 16½ in. bore by 30 in. stroke and the normal speed is 74 r.p.m., corresponding to a piston speed of 370 ft. per min. The foundation dimensions of this unit are 14 ft. 9½ in. by 3 ft. 3½ in., and the machine is equipped with a 15-ft. wheel. The drive is through a 28-in. two-ply leather belt. The motor is an Ideal Electric Co. synchronous, three-phase, 60-cycle, operates at 460 r.p.m. and consumes at rated load 181 kv.a. at approximately 100 per cent power factor (476 amp. per phase at 220 v.). Direct connected to this motor is an exciter unit which delivers 28 amp. at 125 v. to the motor field.

Compressor No. 2 is identical with No. 1 but is ordinarily run at a somewhat lower speed, 70 r.p.m. It is driven by a 24-in. 2-ply belt from a General Electric motor running at 450 r.p.m. and rated at 200 hp. At this rating the power input is 164 kv.a.; 431 amp. per phase at 220 v. The exciter is direct connected as in the first case. It delivers 36 amp. at 125 v.

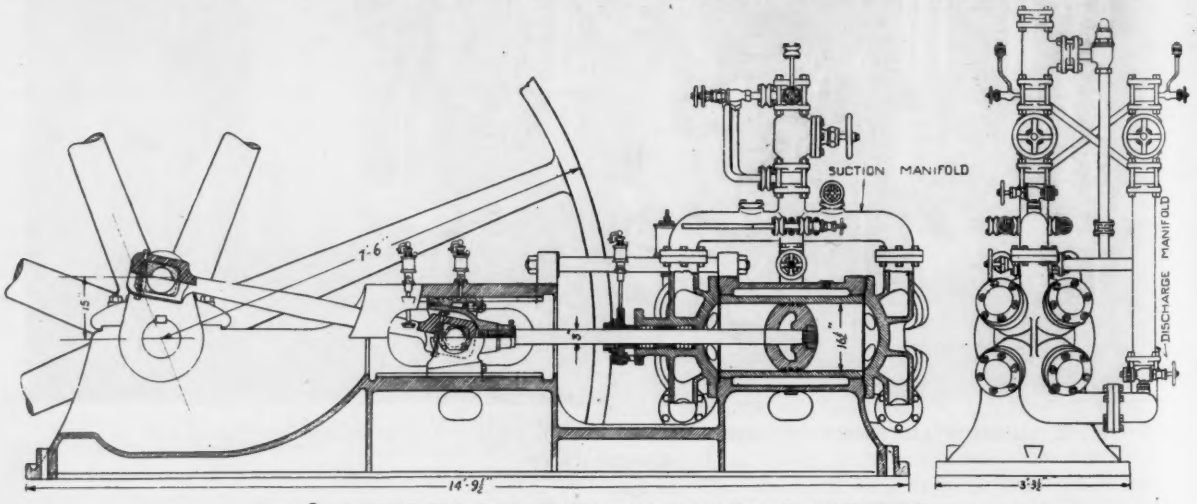


FIG. 3. SECTION THROUGH TRIUMPH ICE MACHINE CO. COMPRESSOR

Number 3 compressor is of the same make and type as Nos. 1 and 2, but is of smaller capacity. The bore and stroke are 13½ by 24 in. and at its normal speed of

80 r.p.m. is rated at 40 T. Like the other two, it is a belt driven unit, the motor in this instance being a General Electric synchronous unit of 150 hp. capacity, the rated power consumption of which is 123 kv.a. or 323 amp. per phase at 220 v. The 45-kw. exciter delivering 36 amp. at 125 v. is direct connected as in the previous cases. This unit is the one shown in Fig. 1. Contrary to general practice in compressor practice, all of these machines run over, bringing the maximum thrust of the crosshead on the upper, rather than the lower guide.

Unit No. 4, a view of which is shown in Fig. 4 A and a section in Fig. 5, is used primarily as a standby to assist in carrying over the peaks and to supply the storage rooms during the off season. This is a 9 by 9-in. York two cylinder vertical single acting, self-oiling unit rated at 25 T. at 150 r.p.m. It is belt driven from a General Electric induction motor running at 855 r.p.m. This motor requires 200 amp. at 220 v. under normal operating conditions.

All units are tied in, in parallel between the suction and discharge headers and so operate under identical conditions.

Current is supplied to the plant at 12,000 v. and is stepped down to 220 v. by means of two systems of three single-phase transformers which supply the busses behind the switchboard.

Ordinarily the suction pressure is maintained at about 30 lb. abs. corresponding to a temperature in the brine cooler of approximately 2 deg. F. The gas comes to the compressor in a saturated condition containing a small amount of liquid.

Cooling water is usually available in such quantities and at such temperature as to result in a discharge pressure of from 190 to 200 lb. corresponding to temperatures of 93 to 96 deg. F., but in extraordinarily hot and humid weather this pressure may run up in the neighborhood of 240 lb. (108 deg. F.).

All compressor motors are controlled direct from the switchboard in the south-west corner of the room, shown in Fig. 6. This board, installed by L. H. Lamont and Co., is made up of six panels. Three contain equipment for controlling the three synchronous motor drives for the horizontal compressors, including operating switches, circuit breakers and field potentiometers. In addition there is also provided two overload inverse time limit relays. One mounts an integrating watt-hour meter and a demand meter and the last two contain a number of small single throw, three-pole switches for minor equipment.

Tank Room

As indicated in Fig. 2, the tank room is immediately adjacent to the compressor room to the west. It is divided into three similar sections, each containing a tank accommodating sufficient cans to freeze about 66 T. of ice per day. There are 29 rows of cans, each, except the eight nearest the compressor room, containing 24 cans. Four cans are taken out of the center of these eight rows to accommodate the brine-cooler. There are thus $24 \times 29 - 4 \times 8 = 664$ cans. Each can is 11 by 22 by 44 in. and holds nominally 400 lb. of water. Actually the weight of each block is 415 lb. so as to insure full net measure after ordinary shrinkage in storage and during delivery is discounted. The tank thus accommodates $664 \times 400 = 265{,}600$ lb., or 132.8 T. and as the freezing time allowed is between 47 and 48 hr., the capacity is $132.8 \times 24 \div 47 =$ approximately 66 T. per 24 hr. As there are three such tanks, the total capacity is 200 T. To insure that the cans be completely frozen in the time allowed, it is necessary to carry the brine at from 12 to 14 deg. F. In order to do this, it is necessary to carry the ammonia temperature at about 2 or 3 deg. F., which

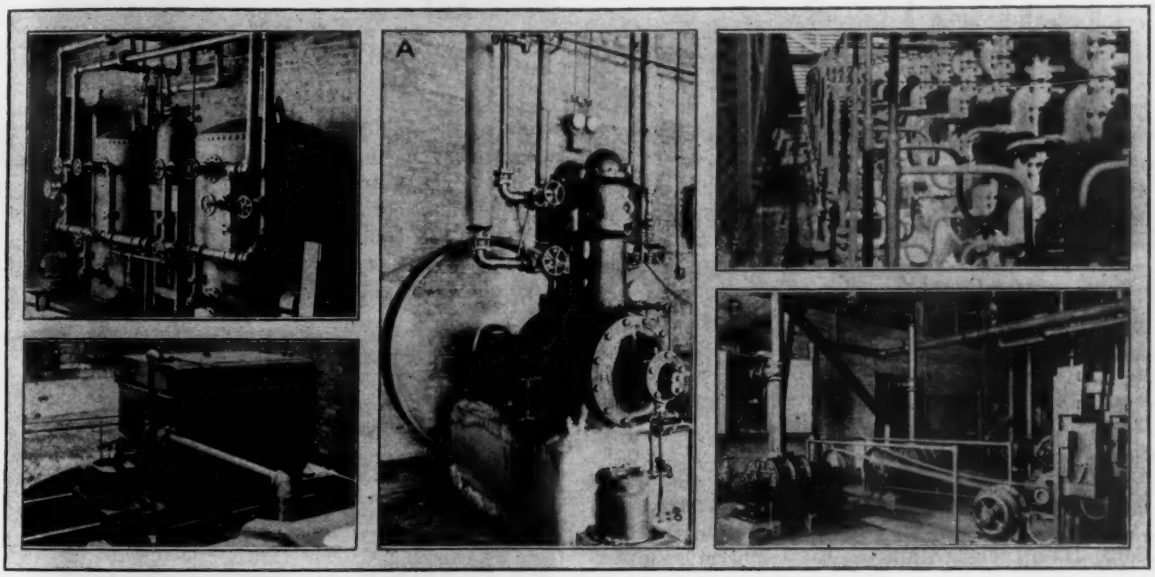


FIG. 4. SMALLER UNITS AT KOSMOS ICE PLANT

A. York cylinder, single acting, vertical ammonia compressor. B. Connerville blowers which supply air for agitation of can water. C. Chemical mixer of the International Filter Co. water softening installation. D. Filter tanks of the water treating system. E. Liquid end of condenser.

allows for a 10-deg. drop between ammonia and brine. This 2 or 3 deg. ammonia temperature corresponds with the 30 lb. suction pressure mentioned in connection with the compressor operation.

Cooling of the brine is accomplished in a shell and tube type cooler located at the east end of the tank. This cooler closely resembles a return tubular boiler; it consists of a shell 54 in. in diameter and 20 ft. long containing 224 2-in. tubes. There are thus 2410 sq. ft. of surface in the tubes and 282 in the shell, making a total of 2692 sq. ft. As the total heat transfer, not allowing for leakage losses, is 12,000 B.t.u. per hr. per ton of ice making capacity, or a total of $12{,}000 \times 66 =$

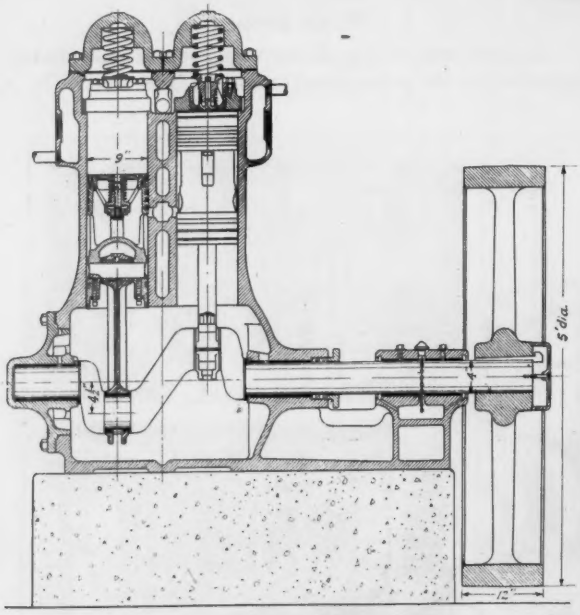


FIG. 5. SECTION OF YORK COMPRESSOR

792,000 B.t.u. per hr., and as the temperature difference is 10 deg., the co-efficient of heat transfer is $792{,}000 \div 10 \div 2692 = 29.5$ (approx.) B.t.u. per sq. ft. per deg. difference in temperature per hour.

To obtain this heat transfer, it is necessary that the movement of the brine over the tube surfaces be considerable. It is also necessary that there be a movement of the brine around the cans. For this reason, there are provided two baffles running lengthwise of the tank, and brine is circulated around them. These baffles are six cans distant from the sides of the tank and run from the bulkhead at the east end to within three cans of the west end. Two 20-in. propellers are mounted in the bulkhead directly opposite the end of the cooler. Each is belt driven from a 7½-hp. G. E. induction motor and the pair handle about 1000 gal. of brine per min. The brine passes through the cooler, down between the two baffles and around along the outside of the tank, back through the bulkhead to the propellers. With this circulation, the temperature drop in the brine from the discharge end of the cooler back to the propellers is from 1½ to 2 deg. F.

Liquid ammonia is supplied at the top of the brine cooler through a reducing or so-called pressure relation valve from the liquid header that runs along the east wall of the tank room. The gas is taken off from the top of the shell and passes to a suction header that runs along immediately adjacent to the liquid line. Both lines are covered by the same insulation. Ordinarily the liquid level in the shell is carried at about ⅔ the

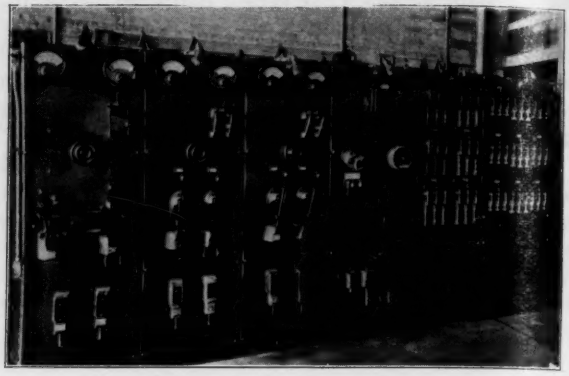


FIG. 6. SWITCHBOARD FROM WHICH THE COMPRESSOR MOTORS ARE CONTROLLED

height of the shell. While this means that some of the tubes are not in contact with the liquid and consequently are not able to transmit their share of the heat, it prevents liquid being short circuited back to the compressor without doing work.

As the cans become completely frozen, they are lifted out from the brine in pairs by an electrically ope-

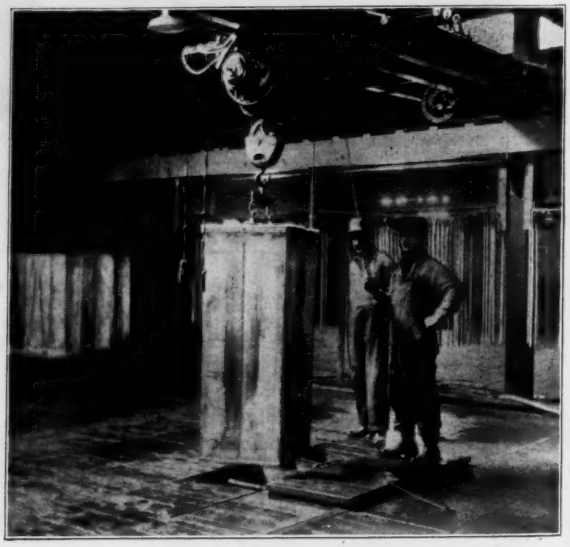


FIG. 7. HARVESTING ICE

rated 1-T. crane and carried to the west end of the room where they are allowed to stand, exposed to the normal temperature of the room for about half an hour, to season. This tends to anneal the cake so that subsequent sudden changes in the can temperature will not cause the cake to crack or chip off. After this seasoning ,the cans are again picked up in pairs by the crane and lowered into the dip tank or so-called hot well where they remain for perhaps half a minute while the cake thaws away from the can. The cans are then hoisted and placed on the dump rack which tilts back and allows the

cakes to slide out of the cans down a runway through the dividing wall into the storage room. The dump rack is then righted and the cans are filled from an overhead tank which contains the exact amount of water required for two cakes. These cans are then replaced in the brine tank in the space vacated by the pair that has just been removed.

Running lengthwise along the tank, between each pair of cans, and just under the flooring, there is a compressed air line having a Triumph automatic valve opposite the center of the can. When the cans are in place, the drop pipes are lowered into position and a connection is made to the valve opening in the air line. Making this connection automatically opens the valve and air under about 5 lb. pressure is admitted to the drop pipes from which it bubbles out into the can and keeps the water in a state of constant agitation.

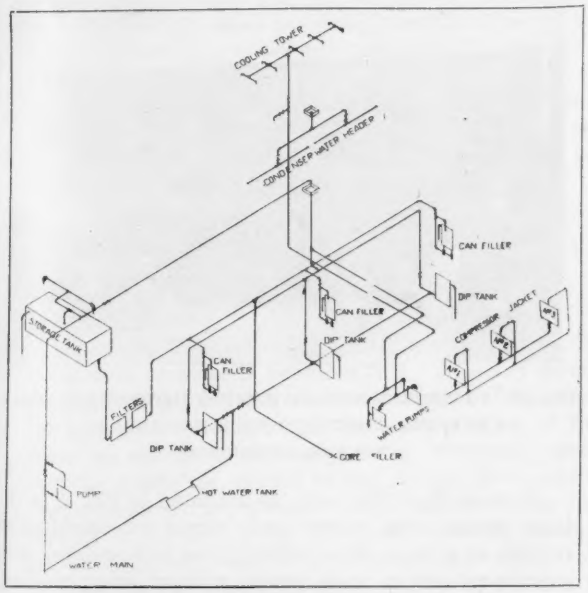


FIG. 8. WATER PIPING LAYOUT OF PLANT

Air for this purpose is supplied by three Connersville blowers, two of which are shown in Fig. 4b. Their location is indicated in the plan of the building, Fig. 2. The third unit is located on a balcony above the compressor room and is not shown. These blowers are rated to handle 1.12 cu. ft. of free air per revolution and they operate at 725 r.p.m. Each, therefore, handles 810 cu. ft. per min. and the total is 2430 cu. ft. per min. Each is belt driven from a 7½-hp. G. E. induction motor running at 1790 r.p.m. and consuming 20.4 amp. at 220 v.

When the ice has frozen practically to the discharge end of the pipe, the drop pipes are removed and the core water is pumped out and replaced with fresh. This is done by means of two hose lines which can be moved about over the tank room floor. One is connected to a small belt driven centrifugal pump at the west end of the room which sucks the cores; the other is connected with a small cold water line supplied by a small direct connected centrifugal pump in the compressor room shown in Fig. 9.

Up until this season water for the ice was taken direct from the city mains and frozen in its natural state, but during the past winter a water softening installation was made for the purpose of producing a better product and for reducing the quantity of core pumped. The water used is Lake Michigan and is not particularly hard nor unsuitable for the manufacture of ice, containing as it does only about 140 parts per million total hardness. This hardness is, however, considerably reduced by softener. The apparatus is the International Filter Co. lime and soda cold process. Analysis of this water indicates the composition to be as follows:

		Parts per Million
Carbonates as	$Ca\ CO_3$	80.
	$Mg\ CO_3$	24.
Sulphates as	$Mg\ SO_4$	7.
	$Na_2\ SO_4$	3.
	NaCl	26.
	$F_2\ O_3$	0.14
	$Al_2\ O_3$	0.5
	$Si\ O_2$	2.
		142.64

Treatment for this condition to reduce the carbonates consists of adding about 1 lb. of lime [90 per cent $Ca(OH)_2$] and ¼ lb. soda ash to every 1000 gal. of water used.

Essentially, the apparatus consists of a vertical wood stave tank, 11 ft. 6 in. diameter by 16 ft. high in which there is a 3-ft. diameter downtake. Mounted on top of this tank is the chemical mixer shown in Fig. 4c, which feeds a given quantity of chemical to the raw water. Lime and soda is added in the desired proportions to the chemical mixer where it is mixed with a small quantity of water. In this tank there is a series of paddle wheels rotating about a horizontal axis which serves to keep the contents in a state of constant agitation and to insure a constant mixture. The end set of paddles is provided with a cup on each blade which dips into the mixture each revolution and brings up a cup full. At the top of the revolution a definite portion of this mixture spills into a trough or funnel from which it flows to the entrance of the down pipe where it mixes with the incoming raw water. This raw water is admitted in such a way as to insure intimate mixture with the chemical. Reaction occurs immediately and the precipitate settles to the bottom.

This newly treated water then emerges from the bottom of the down pipe into the tank proper where it slowly rises allowing plenty of time for the completion of the reaction. A small quantity of alum is added to the raw water as it enters the down pipe to form a flocculent mass that will assist in coagulating the precipitate and decrease the time element involved. The treated water is drawn off from a point near the water level in the settling tank and is passed to a battery of two filters, shown in Fig. 4d. These filters contain layers of graded sand and gravel which serve to remove the last trace of precipitate. From this filter the purified water passes to the three filling tanks where the correct quantity is measured out to be fed to the freezing cans.

In this system, the chemical mixer is so controlled by floats in the main tank that chemical is fed to the raw water in exact proportion to the flow so that complete

precipitation is insured at all times regardless of the demand for water.

Condenser

Compressed gas from the compressors is conducted through a 6-in. header along the roof of the building to the condenser. Here it is divided among three manifolds each of which supplies 11 stands of condenser tubes. There are 33 stands of tubes and each stand contains twelve 2-in. extra heavy tubes, 20 ft. long. The total condenser surface is thus 4150 sq. ft. Gas from each manifold connection enters the bottom tube of each bank and flows up through the bank through the condensed liquid which is draining back. The liquid line taps in at the opposite end of the bank at three points, one at the top return bend, one at the third one down and one at the bottom, as shown in Fig. 4c. This liquid then drains by gravity back to the liquid receiver in the compressor room. The ammonia system, including both high and low sides contains at full charge, about 100 drums of ammonia.

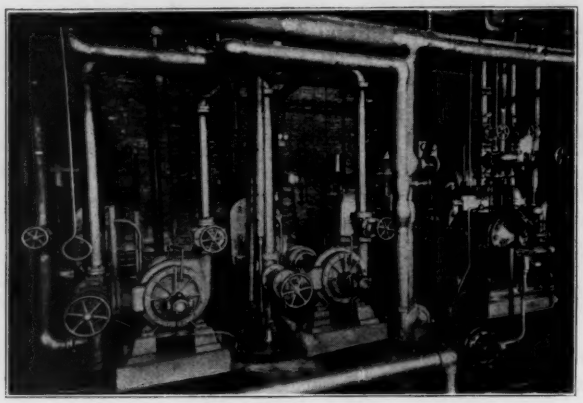


FIG. 9. CENTRIFUGAL COOLING WATER CIRCULATING PUMPS

This condenser is of the atmospheric type and cooling water trickles down over the pipes from a serrated trough arranged along the top of each condenser bank. After the cooling water has served its purpose it falls into a large sump beneath the condenser from which it drains to two parallel centrifugal pumps in the engine room, shown in Fig. 9. These pumps are each driven by direct connected G. E. induction motors rated at 20 hp. and operating at 1760 r.p.m. The power consumption at rated load is 495 amp. at 220 v.

These pumps force the water back to the top of the cooling tower, which is immediately above the condensers. Here the water is admitted to two long level trays, running the length of the tower, through which it falls in small streams onto a system of wood boards beneath. The water covers these and spills over the edges in a rain onto another layer below. This action continues, raining from one shelf to another, until the water reaches the sump below from which it is divided among the several troughs over the condenser banks.

In its tortuous passage down, the water exposes a large amount of surface to the air, evaporation occurs and the remaining water is cooled. To prevent excessive loss by winds blowing the spray away, both the cooling tower and the condensers are enclosed in a housing of inclined slats or louvers, as shown in Fig. 10.

Storage Rooms

Immediately west of the tank room is the small storage room into which ice is delivered from the tank room and from which it is delivered to the loading platform on the north side of the building. This room is 85 ft. wide by 92 ft. long and is high enough to accommodate seven layers of ice blocks laid edgewise, or about 2000 T. It is cooled by means of five banks of coils each containing fourteen 2-in. pipes arranged on the ceiling, along the 92 ft. dimension. The total surface exposed is thus about 3850 sq. ft. Ordinarily a temperature of about 25 deg. F. is maintained in this room by the direct expansion of ammonia in the ceiling coils.

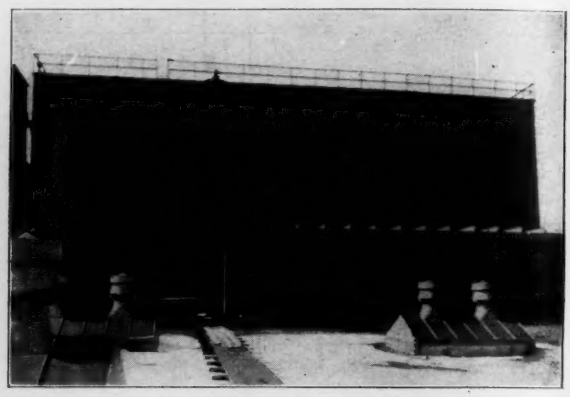


FIG. 10. TO PREVENT EXCESSIVE WINDS BLOWING THE SPRAY AWAY, THE COOLING TOWER IS ENCLOSED IN A HOUSING OF LOUVERS

Just south of this room, as indicated in Fig. 2, is the large storage room where ice is stored for considerable periods at a time. Some cakes in the bottom layer may even carry over a whole season without being touched. The room is 126 ft. long by 22 ft. wide and high enough to accommodate 23 layers of cakes edgewise, or something over 3000 T. The total storage capacity is therefore about 5000 T. The floor level of this room is about 10 ft. below that of the smaller storage room and ice is brought in by means of an elevator operating just inside the door leading into the first room. The room is cooled by means of a double bank of coils along the ceiling and a bank along the east, south, and west walls just under the ceiling. The ceiling coils contain thirty-six 2-in. pipes 122 ft. long and the wall coils six 2-in. pipes about 164 ft long. There is therefore a total of $4400 + 985 = 5385$ of 2-in. pipes or about 3330 sq. ft. total. Direct expansion is used here also and a temperature of about 25 deg. F. is maintained.

Although there is considerably less cooling surface in this room the leakage is much less as there are no windows and only one door in the room and that enters into a temperature of 25 deg.; no difficulty is experienced in maintaining the desired temperature. Larger cooling surface is required in the small storage room to take care of losses occasioned by workmen in the room and the opening and closing of the various doors, communicating directly outside and with the tank room.

Moist Fuels Present Unusual Conveying Problems

CHARACTERISTICS OF VARIOUS CONVEYING SYSTEMS WHICH HAVE BEEN USED WITH SUCCESS AROUND POWER PLANTS. BY ZUCE KOGAN

HANDLING moist fuels is always more complicated than the handling of coal. This is due principally to the different properties of the fuels and the different installations required for the use of the moist fuels. The most important properties of moist fuels are their light weight, softness due to the swelling of fuel fibers after absorbing the water and the variety of kinds, sizes and shapes. Due to these properties, it is usually necessary to employ specially designed conveyors when maximum economy of the working plant is required. Moreover the fuels, when caught between certain working parts of the machinery, as for example between the flights and trough of the scraper or screw conveyors, will not crack and crumble into small pieces as coals would do, but will be compressed even to such an extent that it will result in breaking some parts. The feeding of fuel by gravity from bins into hoppers becomes difficult and at times impossible. The hoppers must be different in form and position, and many other problems differ from those met in designing mechanical means for handling coal fuel.

As to sizes and shapes, moist fuels may vary from powdered saw dust to large logs of wood, the length of the pieces of fuel being the most variable factor.

CHOICE OF CONVEYING SYSTEMS

TO BRING the fuel into the boiler room is the first question to consider in handling fuel. This may involve two conveying problems, the transportation of fuel from the cars to the storage, and the transportation of fuel from the storage to the boiler room. Generally speaking, the conveying of fuel to the storage is a question that is not given much consideration and is usually very difficult to regulate. The transportation from the storage to the boiler room is a question not only of economy in handling, but sometimes some other process could be carried out at the same time, as drying, mixing of fuels, etc., therefore we have to choose the conveying system most adaptable. In this case, methods of conveying may be classified as of three different types: (1) hand labor, (2) mechanical conveyors, and (3) cranes or overhead trolley carriers.

To consider the choice of handling systems, we have to keep in mind that we are dealing with moist fuels, and that we need to take every possible advantage to dry the fuel, because a decrease in moisture-content may increase the calorific value to such a degree that it will overpass the economy gained by using either one or the other type of conveying systems. Conveying of fuel is most economical in large quantities, or by working the conveyor at maximum capacity. This is true with almost any fuel, but especially so with light fuels.

To dry the fuels, they must be exposed to the smallest possible quantities or in the thinnest layers, so as to obtain the greatest exposure to the air. The contrast between economy of handling and drying clearly points out why labor and crane or overhead trolley carriers are not well adaptable. Systems of the conveyor type are therefore probably the best suitable for moist fuels for two reasons: (1) they spread the fuel over a large area, and (2) the conveyor can easily be used in connection with some drying systems as will be discussed in another article. It is the aim of this paper to consider the conveyors only as the handling arrangement for the moist fuels. These conveyors can generally be considered as being of two types: (1) the platform conveyor where the platform and fuel are moving and (2) the scraper conveyor where the trough is stationary and the flights and fuel are moving.

PLATFORM TYPE OF CONVEYOR FOR MOIST FUELS

PLATFORM CONVEYORS seem to be well adapted for the transportation of moist fuel and are usually employed. One of their main advantages is that they permit the fuel to be most uniformly distributed over their surfaces, thus exposing the fuel to the atmosphere or other drying influence. The platform conveyors may be divided into three distinct types as wood, belt and metallic platforms.

Considering the wooden type of platform conveyors, these are not used much nowadays, as there is always a preference for the metallic type. These conveyors have a disadvantage in that the wooden slats may catch and break. Although this does not occur very often, it is something well-known and usually expected by the user. Such a breakdown, although easily repaired, causes great annoyance. On the other hand, however, these are light and require but little power for driving. The fuel being light, greatest economy is secured with light conveyors. These usually serve very well for logs of wood and other similar large pieces of fuel. Although these conveyors are still used in many plants burning small sizes of moist fuels such as bagasse, they are, however, subject to vibration, which causes a portion of the fuel in the form of powder to fall through the space between the wooden slats, making a great accumulation of powder under the conveyor, and fills the atmosphere with dust.

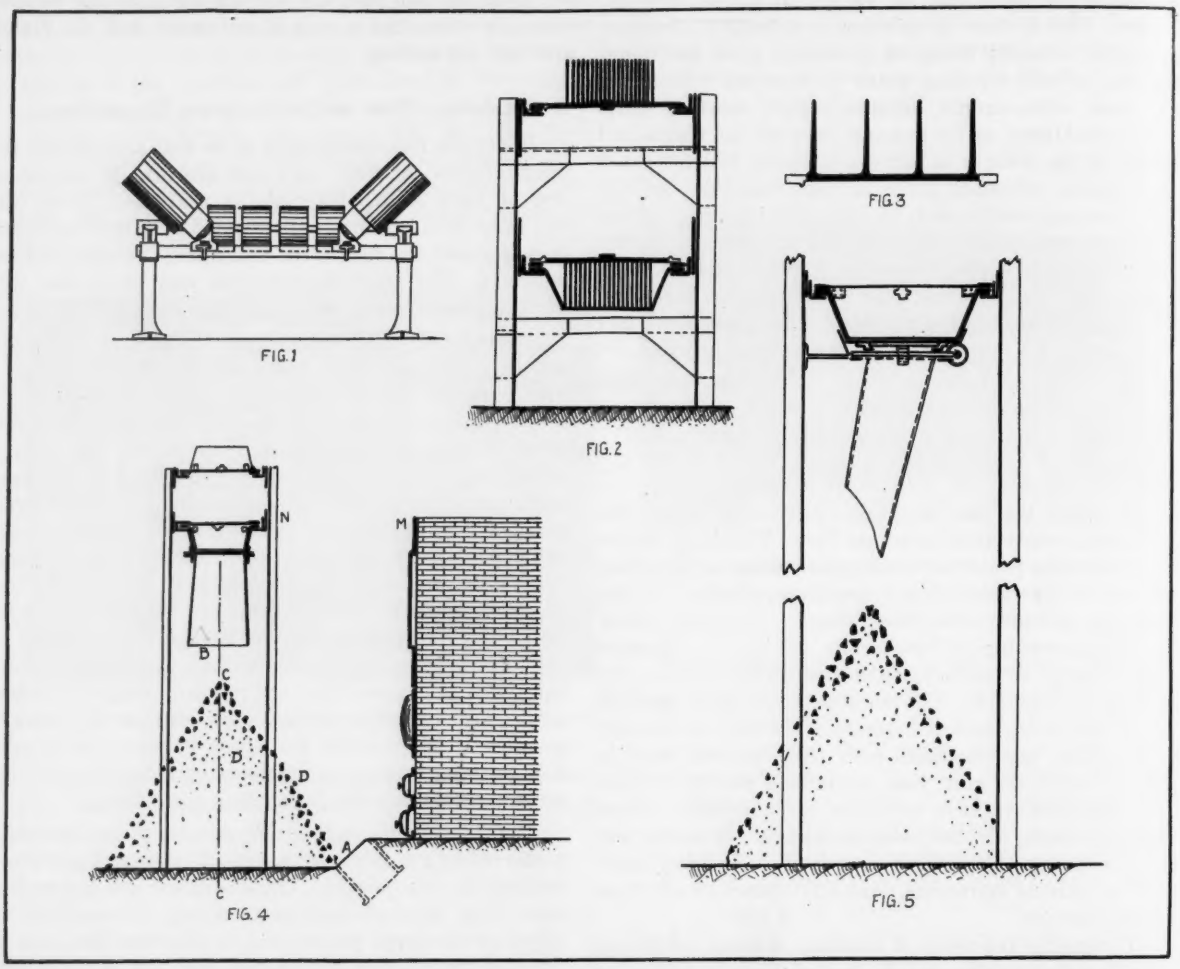
Considering the belt conveyor, this is not generally preferred in a boiler room where the furnaces and steam destroy the belt quickly. These belts are also impractical with large sizes of fuels such as logs of wood, as the edges of the large pieces tend to tear the belt and the unequal distribution of the fuel over the belt will tend to stretch some parts of the belt out of shape. With light and small sized fuels, these are adaptable and cheap. The type shown in Fig. 1 is perhaps the best type for such use. This offset combination troughing will work very economically with the light fuels at high speed and with small sizes of fuel will give a smooth conveying of fuel.

Metallic platform conveyors of slat type are adaptable to all kind of fuels. The slats may be of any desirable shape and therefore could be arranged in a manner to suit best the particular kind of fuel. The slats are also usually bent at the sides forming a side-guard for preventing the fuel from rolling off at the sides thus eliminating the side-frames usually installed with the wooden platform type. The distance between two succeeding slats may be adjusted at will, and the vibration is much

less, thus possessing many advantages over the wooden platform.

Flight Type Conveyor for Moist Fuels

Flight type conveyors which merely push the fuel tend rather to convey the fuel in small heaps than in thin uniform layers and for this reason do not give to the same extent the advantageous features considered with the platform type. This type, however, has an important advantage that is not readily obtained with the platform which is the ease of discharging the fuel at any point type. Both of them are very undesirable with fuels that are thin, especially when these fuels are of very fibrous nature, the reason being that these fuels have a tendency to catch between the flights and trough and result in breaking the flight. In the same way, we may say that the ordinary type of scraper flight is most suitable when the moist fuels are of the cubical shape, while the screw type of conveyor will adapt itself better with fuels in powdered state. There we have to consider that the breaking of flights is more likely to occur with the screw type than with the scraper type, and its use is therefore



FEATURES OF SYSTEMS FOR HANDLING FUELS WITH HIGH MOISTURE CONTENT SUCH AS WOOD REFUSE, HOGGED FUEL, BAGASSE AND STRAW

Fig. 1. Rollers for belt conveyor. Fig. 2. Section of prong type flight conveyor. Fig. 3. The reversed prong type of flight is successful in handling straw. Fig. 4. Fuel piled in front of boiler for hand firing. Fig. 5. Chute designed to distribute fuel to convenient place for fireman.

and at many points. This is of importance in the boiler room, as the (moist) fuel is required to be discharged in equal quantities near every boiler or two boilers. If a platform conveyor be used to convey the fuel from the storage to the boiler, it is preferable to have the part of conveyor contained in the boiler room to be of flight type.

Many types of flight conveyors are in use, but for the general consideration of the moist fuel problem we may classify them under two types: (1) the plain type, and (2) the prong type. Considering the plain type, these may be either the ordinary scraper flights or the screw to be avoided as far as possible. The old V type of scraper conveyor may be used to advantage in some instances. The angle of the V trough will depend on the kind of fuels and their sizes, as for example, for finer fuels the angle must be large, while this angle may be decreased as the fuel is larger in size.

Considering the prong type shown in Fig. 2, this will suit best for fuels that are thin, as any catching of fuel between the trough and flight, will not break the flight, as these bars are elastic and spring away when under strain of the accumulated compressed fuel. The dis-

tance between the prong bars should be suited to the particular sizes of fuel to be used. This type of flight, when reversed as in Fig. 3, is most suitable for straw, perhaps better than any other type on the market, giving a more effective transportation

Discharging Small Sizes of Moist Fuels

Bin arrangement on the hoppers as used with coal is generally not applicable with moist fuels, and even the automatic feeding hoppers can rarely be used with them. For this reason hand firing is generally considered. Such a procedure always requires a small heap of fuel near every one or every two boilers, regardless of the kind of transportation system that brings the fuel into the boiler room. Even when conveyors are used to transport and discharge regularly the quantity of the necessary fuel, we have to take into account that with moist fuel of small size, the feeding is done constantly without rest, and therefore should there not be a heap or a sufficient storage of fuel near the hopper, there may occur a retardation in arrival of fuel, in which case the furnace will be without fuel, and the hoppers open to the atmosphere. The heap of fuel is a very small storage, and is more difficult to maintain than with coal. The reason is that the moist fuel is large in volume per given weight and heat value and therefore occupies a large space in the boiler room. As the fuel is fed constantly, it results that the fuel heap will move too far from the furnaceman and he will require someone to bring the fuel closer to him, this is what usually happens with vertical discharges. To make this clear, we will refer to Fig. 4 in which case the heap D is charged for storage through the vertical discharger B attached to the scraper conveyor. Now let us suppose that the discharger is opened for a small portion of its aperture, just sufficient to allow it to discharge the exact quantity of fuel consumed per given time by the furnace. The fuel falling from the discharger B on heap D will spread equally from both sides of the center CC. As the heap is large, it will result that this heap will become quite a distance from him or from the hopper A as the supply diminishes and as the fuel must be fed constantly without rest, it will need someone to bring the fuel closer to him. For this reason it is advantageous to have the dischargers somewhat inclined as shown in Fig. 5. In this case, the discharger body is made inclined and is fitted with a worm and worm wheel B to rotate about the axis and to adjust the discharging of fuel to suit the convenience of the furnaceman. This inclined rotary discharger is also of advantage when one discharger is to be used for two boilers. It also allows a greater distance M N, Fig 4, from the furnace to the conveyor, which is of advantage.

Position of Hoppers

Handling of fuel as it enters the furnace has also to be considered. This is done by the use of hoppers placed at the furnace doors. These hoppers may have different positions with different moist fuel installations and with different kinds of fuels used. The charging may be done from three different positions:

1. At the front of the furnace as with ordinary coal installations.
2. On top of the furnace when the furnace is extended out from the boiler shell installation.
3. On top of the boiler or from above the boiler shell.

Considering the feeding of fuel at the front, this practice is commonly used with horizontal grates, and although it may be employed with inclined grates it is very rarely used where the inclination is great. As to the kind and sizes of fuels, it may be said that this arrangement is best suited for fuels made up of long pieces, and this is the only convenient manner of feeding such shaped fuels. Such feeding is preferable not only with straw, long leaves, etc., but most especially with wood, for should logs of wood be fed in any other way they would take undesirable positions, causing an increase in drift, inefficient combustion, or the falling of logs will tend to damage the brickwork, etc. This arrangement may also adapt itself well with almost any kind of fuel.

With the Dutch type of ovens charging above the furnace is usually adapted. This type lends itself readily to almost any kind of soft and small sized fuels With horizontal grates, this arrangement permits charging the fuel in cones, which is the most desirable form of fuel bed with moist fuels. With the inclined grate, charging from above is preferable to the front feeding, as these grates are usually long and therefore inconvenient in front feeding. Feeding from above also permits a design of furnace particularly suitable for drying the fuel.

Charging from the top of the boiler is quite similar to charging above the furnace. This, however, is better adapted to the use of hard and long shaped fuels, and especially use with inclined grates. The impact due to falling on the grate will tend it to slide the fuel down from the inclined section to the small horizontal grate, more quickly than desirable. This is, however, of advantage with horizontal grates, as the cone will not be too high, but will cover the grate better and more uniformly while still retaining the advantages of the cone-feeding. It has, however, the great disadvantage that the air entering through the hopper does not pass through the fuel bed and will therefore not come in contact with the fuel, but will, on the other hand, chill the gases and stop combustion.

Need for Care in Reporting Heating Values

Many references in textbooks and in reference books to the heat value of moist and fibrous fuels are entirely misleading, if not useless, states David Moffat Myers in Technical Paper 279, just issued by the Bureau of Mines. In the first place heat values may be reported in a variety of ways, and the absence in such references of definite specifications as to which of four different methods is used render them useless. Further—and equally serious—error may arise from dependence for calorific powers on formulas like DuLong's, which assume that all of the oxygen in a fuel is combined before combustion with the hydrogen in that fuel. The error may be slight in fuels containing but little oxygen, but it becomes serious in woody and many other waste fuels high in oxygen. Calculations containing this common error are unsafe and useless, both for comparison of combustion performances and for predicting results in any problem dealing with these fuels.

Water Column Connections

By H. A. Jahnke

IN SOME boiler plants, the steam gages are connected to the water columns as shown in Fig. 1, to bring the gage in such position as to enable it to be seen better. Frequently, however, we find an installation where the connections between the column and gage are arranged

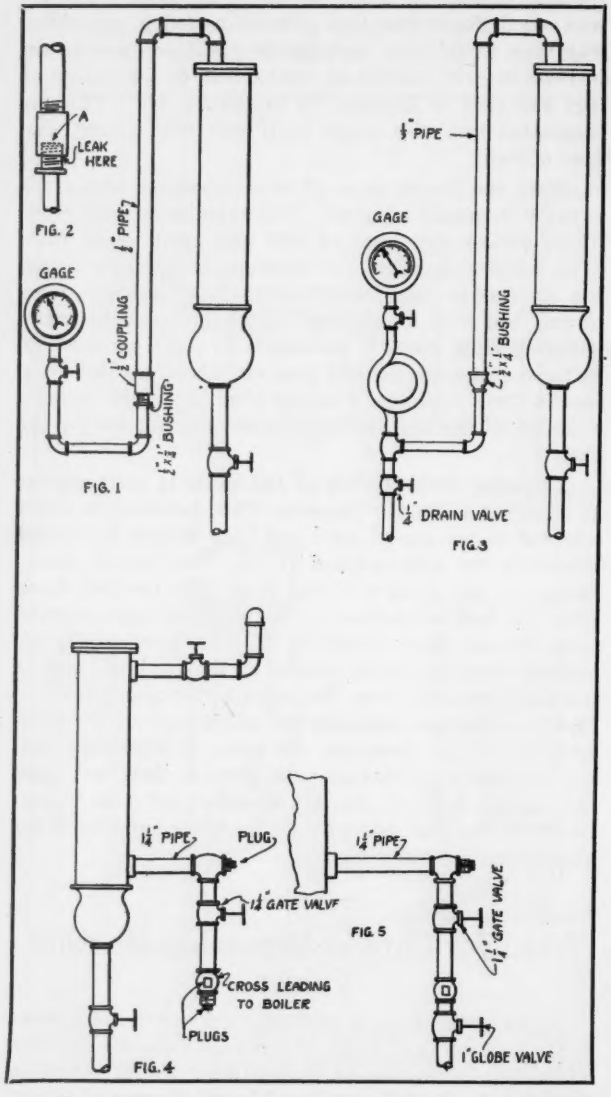


FIG. 1. COMMON METHOD OF STEAM GAGE AND WATER COLUMN CONNECTIONS. FIG. 2. DETAIL OF LEAKY JOINT FIG. 3. REARRANGEMENT OF CONNECTIONS SHOWN IN FIG. 1. FIG. 4. WATER COLUMN CONNECTIONS SHOWING CROSS WITH PLUGS. FIG. 5. PLUG IN BOTTOM OF CROSS (FIG. 4) REPLACED BY NIPPLE AND VALVE

in such a way that there is danger of the gage showing the wrong pressure, due to the fact that some part of the connection is liable to clog up, since there is no way of blowing the connection out at times.

When the writer took charge of his present plant, he found the connection to the steam gage arranged as shown in Fig. 1, where it will be noticed a ½-in. pipe is used for some distance, then reduced to ¼-in. by a ½-in. coupling and ½ by ¼-in. bushing, then the gage is connected up as shown.

Shortly after taking charge of the plant, I noticed a leak at the bushing where it screwed into the coupling. At the first opportunity, I disconnected the gage and pipe up to the ½-in. coupling and found that the bushing was partly eaten away where it screwed into the coupling as shown in Fig. 2, at A and also found that part of the ¼-in. pipe was nearly clogged up. I re-arranged the connection as shown in Fig. 3, by using a ½ by ¼-in. reducing coupling in place of a coupling and bushing and also placed a drain valve, making it possible to blow out some of the scale and other foreign matter out of the connection. I further placed a coil syphon between the gage and tee to prevent damaging the gage when blowing out the connection.

Another Faulty Connection

In other illustrations, we find a condition where some lower water column connections on return tubular boilers are connected up as shown in Fig. 4. In this arrangement, it will be noticed that on the lower pipe coming from the front boiler head there is a cross where the top connection leads to the water column while the bottom and one side outlet is plugged. These plugs are removed at boiler cleaning time to run a rod through the connections.

It is a much better plan to replace the plug at the bottom of the cross with a nipple and valve as shown in Fig. 5, as there is more or less sediment between the cross pipe leading to the front head and the vertical pipe leading to the column. This sediment can be blown out more freely by opening the valve at the bottom of the cross. This arrangement keeps the lower connection more free of sediment than where it all has to pass through the column when opening the blow off on the bottom.

Development of Public Coal Lands

On December 1, there were in effect, under the terms of the general leasing laws, 362 coal prospecting permits, licenses and leases covering 281,818 acres of Government lands in certain western states, according to the United State Bureau of Mines. There were in operation on these lands 77 mines, which had reported to date a production of 833,000 T. of coal. Of a total of 313 coal prospecting permits issued, the largest number, 78, was in Wyoming; 62 permits had been issued in Colorado; 43 in Montana; 29 in Utah; 26 in Oregon; 22 in Nevada, and 20 in Washington. Of 44 leases for the production of coal, Utah, with 15 leases, led; Wyoming, with 8 leases, was second; Colorado, with 7, was third. The total minimum annual production of coal required under the leases granted amounts to 1,559,535 T. It is estimated that there are 311,905,000 T. of coal in lands so far leased.

Gloucester (Mass.) Electric Co. is to construct an addition to the basement of its plant in that city in which to install an additional 1500-kw. turbine, purchased from the General Electric Co. The addition will be of brick, 25 by 29 ft., one story. The condenser and pump will be supplied by the Wheeler Condenser Engine Co., of Boston.

Furnace Design Must Meet Changing Conditions*

INCREASED COMBUSTION RATES, HIGHER TEMPERATURES, DIFFERENT TYPES OF STOKERS AND FUEL BURNING SYSTEMS AND VARYING QUALITIES OF FUEL DEMAND CONSIDERATION WHEN DESIGNING BOILER FURNACES AND SELECTING MATERIAL USED. BY EDWIN B. RICKETTS

YOUR attention is invited to a few of the features of boiler furnace design which, due to the rapid changes which are taking place in the art of burning fuel, are of special interest at this time. The function of the boiler furnace is to supplement the grate or fuel burner in transforming the energy of the fuel into heat and to transfer that heat to the boiler; and the measure of the efficiency of a furnace is the degree of completeness of combustion at the point where the gases enter the boiler tubes and the degree of availability for absorption by the boiler of the potential heat in the fuel at the point where it is delivered to the boiler for absorption—in other words, the per cent of excess air which is necessary to produce complete combustion at the point of exit from the furnace.

Last fall, in connection with the preparation of the report of the Stokers and Furnaces section of the Prime Movers Committee of the National Electric Light Association, I undertook an investigation for the purpose of determining what relation, if any, existed between the relative volume of the furnace and the efficiency of a boiler. This subject being a very live one at that time, I had no difficulty in enlisting the co-operation of nearly all of the engineers engaged in operating the more important public utility plants of the country in furnishing suggestions and test data. This investigation occupied most of the time of several men for three or four months.

In spite of the large amount of time and thought expended, if you will look through the report when it is published, you will not find any conclusions from this investigation because none of us was able to draw any definite conclusions from the data available. A few years ago it was a very rare thing to find boilers provided with more than 1 to 1½ cu. ft. of furnace volume per rated horsepower, but the tendency in modern power stations is strongly toward much larger combustion space. To give an idea of what is becoming general practice today, I have prepared a table showing the cubic feet of furnace volume per rated horsepower in a number of our newest power stations. In the chain grate stoker field you will notice that this ratio runs from 2 in the case of the American Sugar Refining Co.'s plant in Baltimore to a maximum of 4.45 at Calumet. With underfeed stokers this ratio varies from 3.24 at Seward to 4.80 at the Delaware Station. With pulverized coal at Lakeside 4.56 cu. ft. were provided per horsepower, which is being increased to 6.52 at Cahokia, and I know of installations which are at present still in the preliminary stage which will probably have a ratio as high as 10.

I have prepared a second table in which are given (according to the best information I have been able to obtain) the highest B.t.u. fired per cubic foot of furnace volume per hour on tests where the efficiency of boiler furnace, grate and superheater was approximately 80 per cent. In this table there has been included test data running from 78 to 82 per cent, as it is felt that there are possibilities of differences of 2 per cent either way in boiler test results due to experimental errors, differences in skill of operators and condition of apparatus when tested. From this table it is apparent that of the coal firing systems pulverized coal requires by far the largest furnace volume, whereas the same efficiency has been obtained on hand fired Scotch marine boilers when burning seven times as much coal per cubic foot as has been found best suited for powdered coal installations.

TABLE I. CUBIC FEET OF FURNACE VOLUME PER RATED HORSEPOWER (10 SQ. FT. BOILER HEATING SURFACE)

Station	Chain Grate Stokers	Underfeed Stokers	Pulverized Coal
Recent Stations			
American Sugar—Baltimore	2.0		
Kansas City	2.57		
Dalmarnock—Glasgow	3.10		
Barking—London	3.87		
Calumet	4.45		
Waukegan	5.75		
Dodge Bros.		2.17	
Seward		3.24	
Colfax		3.45	
Springdale		3.95	
Hell Gate		4.23	
Gennevillers—Paris		4.50	
South Meadow		4.56	
Delaware		4.80	
Lakeside			4.66
River Rouge			4.98
Cahokia			6.52
Older Stations			
Waterside		1.05	
Essex		1.95	
Muscle Shoals		2.19	
L. Street		2.43	
Conners Creek		2.72	

TABLE II. B.T.U. FIRED PER HOUR PER CUBIC FOOT OF FURNACE VOLUME AT EFFICIENCIES OF ABOUT 80 PER CENT WITHOUT ECONOMIZERS

Fuel Burning System	B.t.u. per cu. ft. Furnace Volume
Pulverized coal	22,000
Chain grate stokers	37,500
Underfeed stokers	64,000
Locomotives	70,000
Oil-steam atomization	85,000
Scotch marine hand fired	144,000
Oil-Mechanical atomization	176,000

For the complete combustion of any fuel, the [illegible] nace volume required is a function of many varia[illegible]

*Paper read before the Metropolitan Section of the A. S. M. E. on March 27. Discussions of this paper were printed on page 451 of the April 15th issue.

among the more important of which may be mentioned: the physical state and chemical composition of the fuel; the type of fuel burning equipment used; the shape of the combustion chamber and the means provided for mixing the fuel and air in the furnace.

Physical State and Chemical Composition of the Fuel

On account of its chemical composition and physical state, fuel oil when burned in modern mechanical atomizer burners is almost ideal in the furnace volume required for its complete combustion. As much as 265,000 B.t.u. per cu. ft. per hr. have been obtained on a White Foster boiler with an efficiency of 76 per cent. This is due to the fact that a large part of the work which in old style burners was performed by the furnace is now accomplished in the burner itself. Oil is heated to about its flash point and is blown into the furnace thoroughly atomized and mixed with the requisite quantity of air for combustion, resulting in a very sharp and intense flame accompanied by complete combustion within a few feet from the mouth of the burner.

Next in order to oil are the lump grades of low volatile coal. With fuel of this kind, the bulk of the combustion takes place within the fuel bed itself or within a very short distance above it. The gas and air leaving the fuel bed are thoroughly mixed and very little furnace volume is required for the completion of combustion. With the higher volatile solid fuels, particularly if they are fired in the form of slack, large amounts of gaseous products are distilled from the fuel bed and frequently the air and gas are in a more or less stratified form requiring either a considerable distance of travel or the provision of certain mixing arrangements in order that the gas may be completely consumed before reaching the cooling surface of the boiler.

Type of Fuel Burning Equipment

Of the type of mechanical fuel burning equipments in common use, the mechanical atomizer oil burner, for the reasons stated above, requires the least help from the furnace. Next in order probably comes the underfeed type of stoker. In underfeed stokers provided with means for continuous ash discharge, due to the depth of the fuel bed and the multiplicity of air openings, a large part of the combustion takes place on the grate and a fairly uniform mixture of air and gases is delivered to the furnace so long as the fire is kept free from holes and large clinkers. Some stratification may take place when too much air is admitted from side wall ventilating systems, but this difficulty is usually easily overcome by altering the size and position of these air openings.

Chain Grate Stokers

In chain grate stokers, that part of the combustion which takes place on the grate is considerably more complicated than with the underfeed type of stoker. Fuel enters the furnace at the front end of the grate where it must be ignited by reflected heat from an incandescent arch. In this ignition process, large volumes of gas are driven off and there is usually a considerable deficiency of air. As the fuel passes further on into the furnace fairly complete combustion takes place on the grate in the center zone while in the rear end of the stoker the last of the carbon is burned out accompanied by a considerable excess of air. We thus have three streams of gas leaving the grate, each being very different in composition, ranging as they do from a stream of gas at the front and mixed with insufficient air for combustion to another stream of gas mixed with a large excess of air at the rear of the furnace. If provision is not made in the furnace for bringing together and mixing these gaseous streams, we may have incomplete combustion and at the same time a large excess of air.

Pulverized Fuel Systems

In the systems for burning pulverized fuel which are finding the most successful applications today, the fuel, together with probably 25 or 30 per cent of the requisite air for combustion, is wafted into the furnace in such a way as to give it as long a travel as possible before reaching the tubes and the air necessary to complete combustion is brought into the furnace through a multiplicity of openings so arranged as to bring fresh streams of air in contact with the coal particles at successive intervals as they travel through the furnaces and while the particle of powdered coal is very small, if it is to be consumed with a minimum of excess air, it is obvious that it must have a long period in the furnace in order to find and combine with those air molecules which are provided for its combustion.

Shape of Combustion Chamber and Mixing Arrangements

It is obvious that a thorough mixture of the fuel and air must take place somewhere in the burning system. If it is not done by the burner or grate, it must be brought about within the furnace. In the mechanical atomizer oil burner, practically all of the mixing is done in the burner itself. Consequently, no mixing arrangements are required in the furnace. In the underfeed stoker, a number of arch and steam jet mixing schemes have been tried but it has usually been found that complete combustion will take place without special mixing device if sufficient height of furnace is provided between the grates and the tubes.

With chain grate stokers an ignition arch is always provided and frequently a reverse arch over the rear end of the stoker, and in some cases a third arch is added over the center of the combustion chamber in order to mix the gaseous streams coming from the three main sub-divisions of the grate and it has usually been found that better results could be obtained the more elaborate the mixing system provided. In the powdered coal systems now in general use, very little of the mixing is done in the burner. There are a number of systems which have been used in an experimental way, in which much larger proportions of the mixing is done in the burner. With these systems it is claimed that a much smaller furnace volume will be required than is now considered necessary, and while it is hoped that the advocates of these systems will be successful in demonstrating this statement, so far it has not been demonstrated on any commercial scale.

On account of the variations in the work which the furnace has to do when used in connection with the various fuel burning systems, it is obviously impossible to make any general comparison of the effect of furnace volume on efficiency. Consequently, the effect of furnace volume must be studied separately for each of the

systems. Very much more reliable test data was available on plants using underfeed stokers than with any other class of equipment and we were able to plot quite a large number of tests where underfeed stokers were used in connection with 14 high Babcock & Wilcox boilers.

None of these furnaces was complicated by arches or other mixing devices, thus eliminating a large number of variable elements and while the curves show a slight tendency toward better efficiency with higher furnace volume, the information is by no means conclusive and the difference indicated may easily be accounted for by test errors or differences in skill of the operator. Furnaces having 3 or 6 cu. ft. per rated horsepower cost a great deal more to build and to maintain than furnaces of smaller sizes. Personally, I have always been an advocate of large furnaces and it would seem, judging from the results shown in Table I, that most of the other men who have to do with the construction of modern power plants agree with me on this point. We, as engineers, should be in a position to prove that any extra expenditure which we make in construction or maintenance is justified by the better economies obtained.

I have given the facts which this investigation of mine has brought to light and I must confess that, if I were called upon to justify the expense involved by large furnace volumes, I would not be able to do it; and it is with the hope that others may succeed where I have failed that I bring this matter to your attention.

Construction of Boiler Furnace Walls

In considering this subject, the first two questions which present themselves are why do we want a wall around our boiler furnace and what are some of the more important characteristics which a perfect wall should possess? We need a wall around our furnaces to direct the heat produced by the burning fuel to the surfaces provided for absorbing it to prevent this heat from being dissipated in all directions where it would be wasted and to prevent excess air from entering the furnace and commingling with the products of combustion.

For these requirements, a perfect wall would be one which, under all conditions of service would be impervious to the flow of gas, air or heat units; it would not crack, spall or soften, and would not be injured by molten slag.

It is well known that our walls fail to meet fully the above requirements and we may profitably consider for a few moments some of the reasons for the shortcomings of present day walls and some of the ways in which these shortcomings may be overcome.

In Table III are given some of the principal characteristics of refractory materials. It would seem at first glance that from this list an almost ideal combination of materials could be selected and if cost were no object, the construction of good boiler walls would be greatly simplified. Unfortunately, however, the cost of some of the more desirable materials is such as to prohibit their use except in small quantities for special purposes. Cost and distribution of raw materials make it necessary for us to rely on fireclay products for the bulk of our boiler wall work.

While the firebrick themselves may fail in a number of ways (several of which ways will be discussed later), usually the weakest part of the wall is the jointing material. Up to the present time, fireclay of approximately the same composition as the brick has usually been found to be the most satisfactory material with which to bond the wall and this material is always more easily disintegrated than the firebrick. Consequently it is advisable that firebrick be obtained with as close uniformity in dimensions as possible so that the amount of jointing material may be reduced to a minimum.

Many attempts have been made to obtain a material better suited to this purpose than fireclay, and, while some of these compounds have given satisfactory results under certain conditions, in many cases the user is paying an exorbitant price for a material having refractory qualities inferior to that of fireclay which forms the base of most of these so-called high temperature cements. The accompanying curves, Fig. 1, show the effect on the melting point of the resulting mixture from the addition of various materials to fireclay.

TABLE III. THERMAL PROPERTIES OF VARIOUS REFRACTORIES

Material	Fusion Point F°	Point of Failure Under 50 lb. Per Sq. In. Load	Thermal Conductivity at 1832° F. B.T.U. Per Hr. Per Deg. F per 1"	Specific Heat at 212° F	Resistance to Spalling
Fire Clay	3092	2462-2552	11.3	.199	Good
Silica	3092	2912	12.7	.219	Poor
Magnesia	3929	2696	22.9	.231	Poor
Chrome	3722	2597	16.5	.....	Poor
Bauxite	3245	2462 or more	11.3	.....	Good
Zirconia	4667	2750	Low	.....	.....
Carborundum	4064	Above 3002	67.0	.186	Good
Alundum	3722	Above 2822	High	.198	Good

Present day tendencies in power plant practice are materially increasing the severity of the conditions under which refractories are used in boiler wall construction. These tendencies are the result of the increasing cost of fuel, labor and equipment, which has made profitable economies in all three of these items which were not to be thought of a few years ago and may be briefly summarized as follows:

1. In order to reduce the amount of boiler equipment for a given output the rate of operation has been largely increased, bringing about increases in furnace temperature and the area of walls exposed to high temperature.

2. Furnace walls are much tighter than formerly and are in many cases protected from radiation and air infiltration by layers of heat insulation and air-tight steel casings, causing dangerous temperatures to penetrate much more deeply into the walls than was the case with the type of construction used a few years ago.

3. The reduction of excess air to a minimum and the conservation of low level heat by preheating the air for combustion, a practice which is common in Europe and which is meeting with increasing favor in this country will probably add several hundred degrees to present furnace temperatures.

An idea of the temperature gradient through boiler furnace walls can be obtained from Fig. 2, which shows the temperature in the walls at the Delray Station of the Detroit Edison Co. These walls are solid firebrick 28 in. thick with no insulation or steel casing. The tests were made with a slight draft inside the setting. at low ratings, the draft being increased with the rating. Considering these results, which were very

accurately obtained by imbedding thermo-couples in the wall at various distances from the fire face, we can readily see that when ratings are pushed up to 400 per cent the addition of possibly 200 deg. by air preheaters we will have a furnace wall temperature close to 2900 deg. F. if we continue the type of wall construction now generally used.

Furnace wall temperatures are affected to a considerable extent by the relative pressures on the two sides of the wall. This effect is clearly shown by some tests made by R. M. Howe on an experimental furnace at the Mellon Institute.

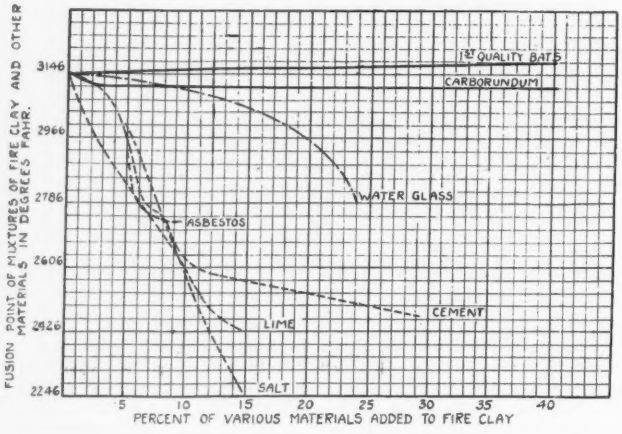


FIG. 1. IMPURITIES IN FIRE CLAY LOWER THE FUSING POINT

Temperature of the furnace wall was measured at a point ½ in. back from the inside edge of the furnace under varying conditions of draft in the furnace with results as follows:

Furnace temperature was 2440 deg. F.; with a slight draft the wall temperature was 2030 deg., with 0.05 pressure 2300 deg. and with 1 in. pressure it rose to 2380 deg. The importance of avoiding a positive pressure in boiler furnaces cannot be over-emphasized, as it is one of the most prolific causes of wall failure.

Assuming that the furnace wall has been skillfully constructed with high grade fireclay materials, what are the principal causes of wall failure, and how may they be avoided?

We have seen from Table III that the melting point of first class fireclay refractories is well above furnace temperatures of which there is any immediate prospect; consequently, except in cases where an oil or gas flame impinges directly against the furnace wall, a condition which is usually readily remedied by the selection of suitable burner equipment, there will be little trouble from straight fusion of the furnace lining.

Again referring to this table, we see that fireclay bricks begin to soften under load at 500 to 600 deg. below their melting point. With the old style low set boilers, this was not a very important feature because the surface exposed to high temperatures was small and the superimposed loads light. With modern high set boilers, however, this characteristic of firebrick has assumed increasing importance. The liability of failure from this cause is a function of the depth of penetration in the wall of a temperature which would cause softening and of the shape of the wall. A study of Fig. 3 will show what is meant by the latter statement. To the left is shown the front wall of an underfeed stoker setting which is corbelled in such a way as to impose a very heavy load on the course of brick just above the ram box caps. It will readily be seen that a slight softening of the lower rows of brick will cause the whole front wall to fall into the furnace. The

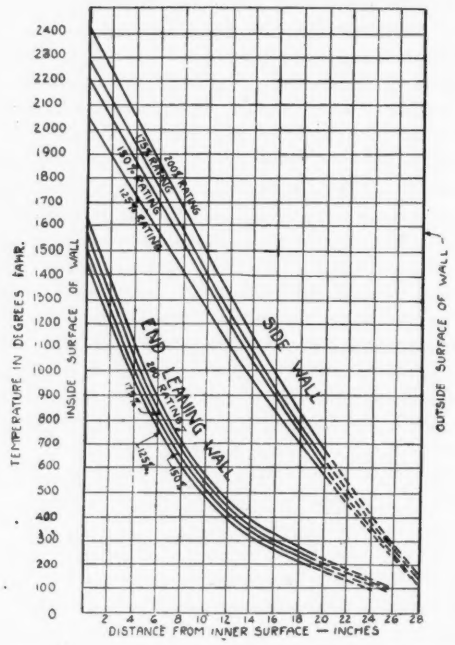


FIG. 2. TEMPERATURE GRADIENT THROUGH WALLS OF DELRAY BOILER FOR VARIOUS BOILER RATINGS

life of this wall was only a few weeks and has been replaced by the one on the right which has given several years' service with no trouble.

Study of a large number of reports on the life history of walls all over the country has indicated that the wall which leans in toward the furnace is a constant source of trouble.

Erosion of firebrick by molten ash is responsible for more furnace wall failures than all the other causes put together. Where coals are used having a high ash fusion temperature, say 2700 to 2800 deg. F., ash erosion is not important; but such coals are scarce now and becoming more so every day, and our furnaces must be so constructed that they will function successfully with coals, the ash of which begins to soften at 2100 deg. and runs at 2300 deg.

Where a pulverized coal or forced draft stoker flame strikes the furnace wall, the effect of ash erosion is most pronounced. These flames carry small particles of molten ash which penetrates any cracks or pores in the brickwork. The surface of the wall then becomes a mixture of firebrick and ash which has a melting point much lower than firebrick.

Coal ash is not a definite chemical compound but is a mixture of many compounds. It, consequently, has no definite melting point like ice, but changes state gradually; frequently there is an interval of 200 to 300 deg. between the first signs of softening and the point where

the viscosity has been so reduced that it will readily flow.

Ash erosion is a function of the depth of penetration of the ash flow temperature into the furnace lining, the porosity of the wall, and the relative composition of the refractory and the ash with which it comes in contact. The manner in which this erosion takes place is well illustrated in the accompanying diagram, for which diagram and its explanation I am indebted to an article by Henry Kreisinger in the 1922 Prime Movers Committee report.

"If the surface of the furnace lining is below the running temperature of the ash, the molten ash coming in contact with it is cooled to the temperature of

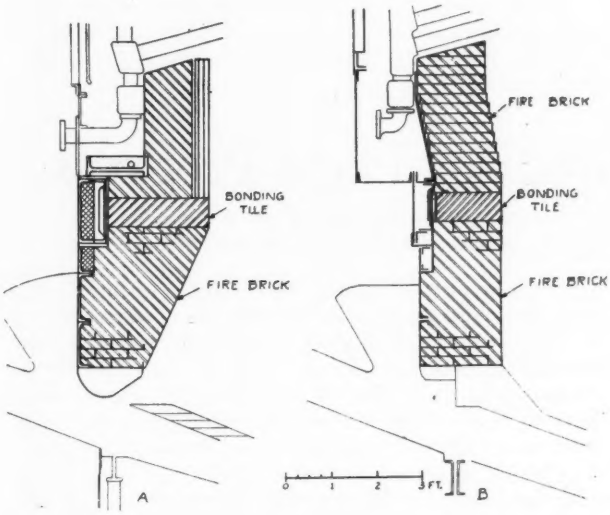


FIG. 3. INWARD SLOPING WALL AT THE LEFT HAD A LIFE OF ONLY A FEW WEEKS AS COMPARED TO SEVERAL YEARS FOR THE WALL AT THE RIGHT

the brick and becomes thick viscous fluid adhering to the brick and moving slowly over the surface. Owing to its high vicosity, the ash does not penetrate into the brick and will not wash it away, but forms a pasty coating over the surface of the brick. The thickness of this coating depends on the interval between the softening temperature and the running temperature of the ash, and on the rate at which heat passes through the layer of pastry ash and the brick. The surface of the coating away from the brick is at the running temperature and any further deposit of molten ash will run down over the coating without harming the brick. This condition is shown in Fig. 4, by the temperature gradient AB. The length of arrows near the surface of the brick indicates the speed at which the various layers of the coating of the ash move. The heads of the arrows form a curve A'B'.

"If the surface of the brick is at the temperature of the running ash, the ash penetrates to a small extent into the brick and the abrasion of the furnace lining begins. This condition is illustrated in Fig. 4 by the temperature gradient CD. The curve of the moving slag is shown by the dotted line C'D'.

"A temperature condition very destructive to the brick lining is shown by the gradient EF. The temperature of the running ash is one inch within the brick and the molten ash penetrates into the brick rapidly and washes the brick away."

Depth of penetration of dangerous temperatures in furnace walls with a given furnace temperature is

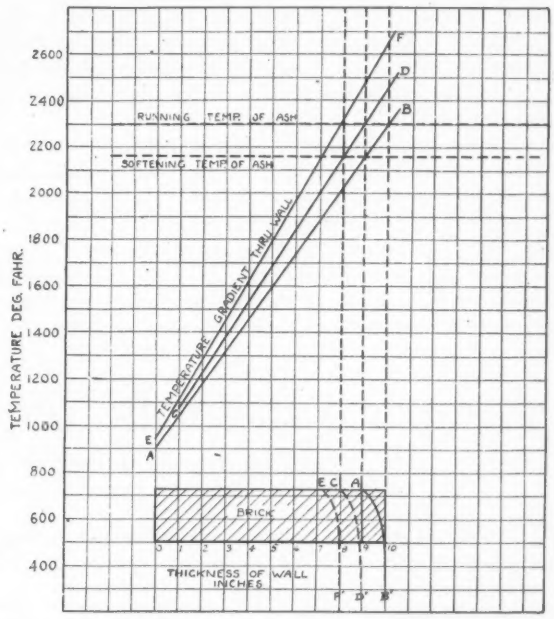


FIG. 4. ABRASION OF WALL STARTS WHEN TEMPERATURE OF BRICK REACHES RUNNING TEMPERATURE OF ASH

largely influenced by the material of which the wall is constructed, its thickness and the velocity of air currents against the outside of the wall.

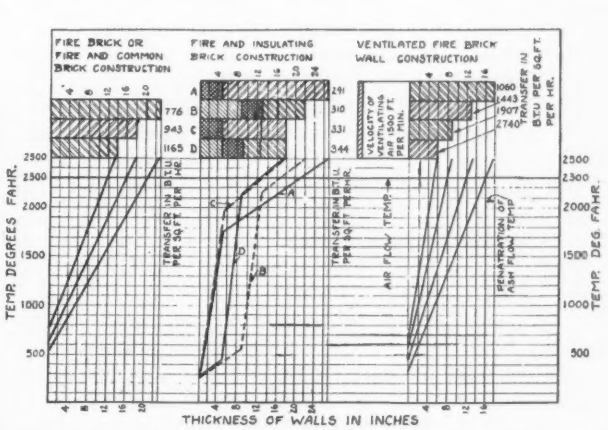


FIG. 5. EFFECT OF TYPE OF FURNACE WALL CONSTRUCTION ON THE PENETRATION OF DANGEROUS TEMPERATURES INTO BRICKWORK

To show the effect of these items, I have prepared the diagram which is shown in Fig. 5. In preparing this diagram, it was assumed that the furnace was operated in such a manner as to maintain a temperature of 2500 deg. F. at the inner edge of the wall; that the coal burned has an ash softening point of 2300 deg. and the ash flows at 2100 deg. F. To the left are shown various wall thicknesses of solid firebrick. In

the center we have walls composed of a combination of firebrick and insulating material which is assumed to have 0.1 the heat conductivity of firebrick and on the right is illustrated the hollow wall construction where the air for combustion absorbs the heat radiated through comparatively thin walls. A study of these diagrams clearly illustrates the danger of using insulation in furnace walls where the walls are not provided with any cooling arrangement and the advantage of the hollow ventilated wall construction where high combustion temperatures are being dealt with.

If we would obtain the highest efficiency coupled with long wall life, the walls must be so constructed that air cannot leak into the furnace and a minimum of heat will be radiated from the walls. This must be done while burning the fuel with a minimum of excess air which has been preheated several hundred degrees. Obviously, walls made of fireclay brick will not stand such punishment unless some means are provided for reducing the wall temperature relative to the combustion temperature in the furnace.

In the Lopulco system of burning pulverized coal a combination of air and water cooling of furnace walls has worked out satisfactorily. This system of cooling the walls by heating air for combustion is well suited to conditions where it is desirable to introduce a large part of the air for combustion as secondary air, but would not be very desirable in combustion systems where all or a large part of the air is primary air, such as stokers, mechanical atomizer oil burners and certain powdered coal systems. Another difficulty with air cooled walls is that it makes it more difficult to use low level heat which is available at slight expense for preheating combustion air.

In my opinion the present tendency of boiler furnace design is toward a furnace in which combustion will take place entirely surrounded by water and steam cooling surfaces.

Accurate Records Required for Plant Progress

CONDITIONS MAINTAINED, QUANTITIES INVOLVED AND FINANCIAL EXPENSES WHEN CONSISTENTLY COMPARED POINT WAYS TO IMPROVEMENTS. BY JOHN M. DRABELLE*

POWER PLANT records and statistics divide themselves into three rather broad, yet closely inter-related groups:

(a) Operating
(b) Quantitative
(c) Financial.

Group "a" deals with the direct operating characteristics of plant equipment, such as bearing temperature, transformer temperatures, draft over fire, r.p.m. of stokers, boiler water feed temperatures, and such kindred subjects. These are of direct interest to the power plant chief and present to him a picture of the direct details of the plant operation hour by hour. Such log sheets as these, if carefully made up and the actual readings of the instruments recorded thereon, give a very desirable record and are particularly valuable in case of trouble where disputes may arise as to what went on from hour to hour in order to determine the cause and fix the blame. These log sheets are often, unfortunately, merely glanced at by the chief and to the watch engineers and firemen just another part of the deadly routine of operation.

(b) Quantitative records are of particular interest to the up-to-date and wide-awake chief engineer who today is being found in more and more of our power stations.

An auditor of a large middle western public utility has aptly stated in regard to the record system, "Records of any kind are only so good and worth only as much as the information at the source is accurate, reliable and honest." This is really a great truth and deserves to be posted up in every power plant office. There is no use in making a fine record on coal per kilowatt and then in a couple of months' time find that the so-called storage pile has vanished into thin air, a readjustment of charges made and the good coal record as "will o' the wisp" and for many months thereafter the records are always taken with a grain of salt and with much doubt by the company executives.

Coal scales must be checked regularly, water meters checked and watthour meters tested so that these three fundamental quantities may be definitely fixed; they have to be accurate and constant checking is the only way to secure that accuracy. No matter what your results are, have them accurate, reliable and honest ones and then after this is done take the proper and rather simple corrective steps to bring your station up to the standard that it is capable of producing. Above all in the compilation of your records, be honest with yourself and don't indulge in "fudging" and "kidding" yourself.

What should these records show and what is necessary to know about the day to day results? The first requirement is that the plant should be equipped with certain recording and integrating devices. Let us assume a power plant of an electric light company. The principal commodities used are coal, water and labor and the product, kilowatt-hours.

In Fig. 1 a typical plant report is shown which is the daily station report of the Boone Generating Station of the Iowa Railway and Light Co. This station furnishes the usual light, railway and power service and in addition heating service is furnished by a hot water heating system. This form was designed with the idea of having the meter dial reading show the respective meter constants and the difference so that fundamental or original data would at all times be available for the auditing department as well as the derived data or, as more commonly termed, the daily results. This form gives the plant chief, the division manager, the operating department and the accounting department a complete picture according to the various interests of what goes on from day to day.

At the end of the month summaries of these daily reports in graphic form are sent to the division manager, the station chief and the executives. These show

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the variation in daily output, the coal burned, the water evaporated, and outside temperatures, heating system temperatures, as well as derived results, such as evaporation, pounds of water per pound of coal, water per kilowatt-hour, etc. A study of these daily reports and graphic charts gives the plant chief a concise statement of just where he stands in regard to today, last week, a month and a year ago.

Records of this kind, however, are in the same class as recording instruments; unless checked, studied and and gives a summary in dollars of the monthly operations. Too many chiefs regard the accounting department and the auditor as their sworn enemies and nothing could really be further from the truth. It is quite true that the accounting department may not know the difference between standard and extra heavy fittings and when to use a globe and when to use a gate valve, but they do know where and how the money was spent. It is true that coal per kilowatt and water per kilowatt is desirable information; but maintenance of boiler

Form—R-137

Boone Daily Station Report

Day Ending Midnight 19

No	Reading	Difference	Const.	K W H
15				
16				
17				
Total Generated				
1			100	
Totalizing Meter				
2			10	
Total M. G. Set Input				
3			10	
5			10	
7			10	
Total Feeders				
4			10	
Total 13200 V. Trans. Input				
6			10	
Total Station Light and Power				
8			10	
Total Heat Pump				
11			1	
12			1	
Total Series Arcs				
9 OUT			100	
13 IN			10	
14 IN			10	
Total 33000 V. High Tension Input				

No.	Reading	Difference	Const.	K W H.
9 IN			100	
13 OUT			10	
14 OUT			10	
Total 33000 V. High Tension Output				
10			10	
Total D. C. Ry. Output				

SUMMARY

Total Generated	
Station Light and Power	
Net Generated	
Total Received—9 in.	
Total to Account for	
Total Feeders, Less 11 and 12	
Heat Pump	
Motor Generator Set Input	
Total Series Arcs	
Transformer Input 4 and 6 Out.	
Total Used	
Unaccounted for	

LOSSES

33000 V. Transformer Input	
33000 V. Transformer Output	
33000 V. Transformer Losses	
Input to Motor-Generator Set	
Total D. C. Output	
Motor-Generator Losses	
Total Losses	

STATION MAXIMUM DEMAND

Time			Generators On.	K. W. H.
		M		
		M		
		M		

Max. Ry. Load Amperes

VACUUM

Time	Barometer	No. 1	No. 2	No. 3
7 A. M.				
10 A. M.				
2 P. M.				
6 P. M.				
10 P. M.				
Average				

DIRECTION OF WIND

WEATHER

Max. Temp.	Min. Temp.	Mean Temp.

MACHINE	On	Off	Time Operating
Gen. 1 (800 K.V.A.)			
Gen. 2 (800 K.V.A.)			
Gen. 3 (1000 K.V.A.)			
Total Generator Hours			
Steam Exciter			
Motor Exciter			

BOILER HOURS	Cold	Banked	Active
Boiler No. 1 (420 H.P.)			
Boiler No. 2 (420 H.P.)			
Boiler No. 3 (420 H.P.)			
Boiler No. 4 (420 H.P.)			
Total Boiler Hrs.			
Boiler H. P. Hrs.			
Boiler H.P. Hrs. per K.W.H.			

Water	Average Temperature
Boiler Feed	°F.
Circulating in	°F.
Circulating out	°F.
Heating System in	°F.
Heating System out	°F.
Average Steam Pressure	Lbs.
City Light On	M Off M

GROUND TEST

Phase	12 P. M.	12 Noon	6 A. M.
A.			
B.			
C.			

No.	Reading	Difference	Const.	Lbs.
18				
Live Steam to Heat System				
19			100	
Water Evaporated				
20			1	
21			10	
City Water—Gallons				
22			10	
23			10	
Oil Burned—Gallons				

Oil per Gallon	Lbs.
Oil Burned	Lbs.
Coal Burned	Lbs.
Water Per Lb. Coal	Lbs.
Water per Lb. Oil	Lbs.
Water per K. W. H.	Lbs.
Coal per K. W. H.	Lbs.
Oil per K. W. H.	Lbs.

LABOR

	Hours	Cost	Comments
Construction Boiler Plant			
Construction Engine Plant			
Total Construction			
Total Construction to Date			
Maintenance Boiler Plant			
Maintenance Engine Plant			
Total Maintenance			
Total Maintenance to Date			
Operation Boiler Plant			
Operation Engine Plant			
Total Operation			
Total Operation to Date			

Unusual Occurrences

Signed

FIG 1. ESSENTIAL CONDITIONS OF OPERATION AND QUANTITIES INVOLVED ARE RECORDED DAILY ON THIS SHEET

analyzed they do not of themselves produce results, but to the man who will push a pencil a little they are of inestimable value and the man who will study and analyze his results today, public utility executives are not slow in giving him more equipment, better equipment and a raise in pay. Too many men, because executives will not make a large outlay of capital and buy everything in the catalog, are disposed to throw up their hands and say, "What's the use?" The real test of a man is to produce results under unfavorable conditions and with inadequate equipment.

Group "c" are the records as compiled by the accounting department and in the last analysis are those which the executive understands and by which the chief is really rated. This form is shown in Fig. 2 plant in dollars, the fuel cost for the month and the cost per kilowatt-hour generated are equally deadly and pertinent facts, particularly to executives who must answer to the stockholders in dividends.

It will be noted that this form gives this month, the same month a year ago and a recapitulation of the total of the months of the year to date and for two years prior, also the increase or decrease.

An intelligent chief will not pass such information idly by, for one of the greatest evils around a station is to bunch maintenance; this is particularly true in the boiler plant and only to a lesser degree with the machine room, the tendency being to get a big gang together and go through the boiler, causing a heavy charge all in one month and the results obtained

thereby not reflecting the true condition of affairs in the station.

Steam plants are divided into two groups, boiler and engine plant, and the work in each in two groups, maintenance and operation. These items bear a very direct relation one to another; if, for example, the boiler plant maintenance is neglected in an effort to make a paper showing, the operation item "Fuel for Power" will show the effect of such a policy in about 30 days. The plant which shows a rather uniform and constant expenditure for this item will on examination be found to be in better physical condition than the

ELECTRIC AND STEAM DEPARTMENTS
DETAILS OF BOILER AND ENGINE PLANT
OPERATING EXPENSES

	MONTH OF 1	2	3 INCREASE DECREASE	4 MONTHS TO DATE 5	6	7 INCREASE DECREASE
Boiler Plant						
Maintenance						
701 Supt. Boiler Plant Maint.						
702 Maint. Coal Storage Plant						
703 Maint. Powerhouse & Fix.						
704 Maint. of Boiler Plant Equip.						
705 Maint. Coal Handling Appar.						
Total Maintenance						
Operation						
712 Supt. Boiler Plant Oper.						
713 Boiler Room Labor						
714 Fuel for Power						
715 Oper. of Coal Storage Plant						
716 Water for Power						
717 Mis. Sup. & Exp. Operation						
Total Operation						
Steam Trans. to Other Dept.						
Net Operation						
Net Maint. and Operation						
Engine Plant						
Maintenance						
706 Supt. Mach. Room Maint.						
707 Maint. Prime Movers						
708 Maint. Elec. Equip.						
709 Maint. Prime Mover Tls. & Equip.						
710 Depre. of Steam Power Plant						
711 Equal. Steam Power Plt. Maint.						
Total Maintenance						
Operation						
718 Supt. Mach. Room Opr.						
719 Machine Room Labor						
720 Lubricants for Power						
721 Mis. Sup. & Exp. Steam Gen.						
Plant Machine Room						
Total Operation						
Total Maint. & Operation						
Total Steam & Elec. Plant						
Hydro Electric Plant						
Maintenance						
725 Supt. Maint. Hydro-Elec. Plant						
726 Maint. Dams, Canals & Pipe Lines						
727 Maint. Hydro-Elec. P. Plt. Bldgs.						
728 Maint. Wheels & Governors, H. E.						
729 Maint. Elec. Equip. H. E.						
730 Maint. Pwr. Plt. Tools & Equip.						
731 Deprec. of Hydro-Elec. Pwr. Plt.						
732 Equal. Hydro Plant Maint.						
Total Maintenance						
Operation						
733 Supt. Oper. Hydro-Elec. Plant						
734 Hydro-Elec. Plant Labor						
735 Dam Rent—H. E.						
736 Electrical Labor—H. E.						
737 Lubricants for Power—H. E.						
738 Misc. Sup. & Exp.—H. E.						
Total Operation						
Total Maint. & Operation						
Power Purchased						
From other Companies						
From other Divisions						
To other Divisions						
To other Departments						
Net Pr. Pur. or Trans.						
Net Production Expenses						

FIG. 2. ON THE RESULTS TABULATED IN THIS MONTHLY FINANCIAL STATEMENT THE EXECUTIVE JUDGES HIS OPERATING FORCE

one that shows a great variation and a check of the item of "Fuel for Power' and the coal per kilowatt will show the fallacy of such a policy.

Another tendency on the part of station chiefs is periodically to "stock up" on supplies and this is clearly shown in the variation of accounts 717 and 721, Miscellaneous Boiler and Engine Plant Supplies. The chief who keeps track of his supplies in his storeroom and orders additional supplies as the various items reach a certain number, avoid radical fluctuation in these accounts. Too many men never give these storerooms a thought until some supply salesman comes along and then they feel compelled to place a few requisitions. The journeys of the packing, paint and oil salesmen over a large holding company's property can be clearly traced by the requisitions on the purchasing agent's desk.

In power plant operation, the great problem is not one of instruments, boilers, stokers, or prime movers, but of the loyalty of men. I have seen many a plant with rather mediocre equipment and a total lack of so-called refinements, producing relatively better results than a plant equipped with the last word in everything. The answer is in the personality of the station chief and the men with which he has surrounded himself. This man then given an adequate instrument equipment will, with the co-operation of the accounting department, produce some really astounding results. Why? The answer is, he will translate a rather dead set of figures into a living thing to his men, who will respond because it is for the good of the chief and the plant.

With reports and statistics, the greatest problem is so to arrange, prepare, and present them that they may be readily understood and appreciated by men who are not accountants, trained statisticians or technical graduates, but Bill, Jack and John, who are firemen, watch engineers, and switchboard operators in whose hands in the real and last analysis the results of the station rest—this is the rock on which the ship of the so-called efficiency engineer generally wrecks itself.

Fuel Saving Effected by Combustion Control

EXTENT OF POSSIBLE SAVINGS IS DEPENDENT UPON THE ORIGINAL CONDITIONS OF OPERATION. BY T. A. PEEBLES*

IS IT POSSIBLE to save 5, 10 or even 20 per cent of my present fuel bill without building a new plant or making expensive improvements in the existing equipment? Many engineers and executives have asked themselves this question and if they have reached the conclusion that it is not possible, it must be admitted that there are reasons for such a decision.

Most engineers have been approached many times by salesmen who guaranteed a definite saving, sometimes as high as 20 per cent, by the use of their equipment. It was only necessary to put in enough of these various devices and then watch the fuel bill approach the vanishing point, provided, of course, that the salesmen knew what they were talking about. The whole thing is so absurd that the busy engineer or executive may finally decide that all such devices are of the "gold brick" variety. It becomes even more absurd when the salesman makes his guarantee without even seeing the plant or having any knowledge of the equipment or methods of operation. One engineer tells the story of a salesman who came to him with a guarantee of 15 per cent saving in fuel by the installation of his apparatus regardless of what the present equipment might be. The engineer called his assistant and instructed him to take the salesman to the boiler plant, assist him to get the necessary data and dimensions and then bring him back to the office where they would get the order made out. The assistant returned in a few minutes—alone; the salesman had gone out by way of the alley when he found his own apparatus installed and operating in not the most satisfactory manner.

Buyers find it difficult to separate the good from the bad because each salesman backs up his verbal guarantee with letters from a number of users of his product who report savings even greater than the guarantee. He neglects, however, to explain that the writers of these letters had failed to analyze properly the reasons for the improved results. The man who installed the "fuel saving equipment" probably found badly cracked boiler settings, baffles in poor condition or entirely missing, tubes dirty both inside and out, blowoff valves and steam traps leaking and other sources of unnecessary losses. He had these conditions corrected and was then able to run a test showing a surprisingly large saving and his equipment was given credit for the improved results, when, as a matter of fact, the improved general conditions were largely responsible.

It is possible to effect large savings by the careful selection of inexpensive equipment and the plant engineer and executive can well afford to give such matters careful study. They must first determine whether or not the claims made for a certain piece of apparatus are reasonable. Is it reasonable to believe that the difference between the actual existing conditions and those which certain apparatus will maintain would result in a substantial saving? Judged by this standard, the greatest opportunity for saving lies in the correct control of combustion.

Each time a fireman reports for work he is given a share of his employer's money to spend. It is given to him in the form of fuel which may amount to $50 in a small plant or as much as $500 in a larger plant. He uses whatever he requires to do the day's work and every engineer knows from experience that one man will use much more than another and that the difference is due to the greater skill and care on the part of the fireman who uses the smaller amount. The difference lies in the manner in which the better fireman supplies fuel at the proper rate to meet the load demand and adjusts the air supply to burn the fuel most efficiently.

It has been proven repeatedly that these adjustments can be made more promptly and more accurately by correctly designed apparatus than by hand, and the results are reflected in reduced fuel bills. It should not be assumed, however, that automatic apparatus can take the place of a capable fireman. It rather assists him and makes it possible to get even better results. Automatic apparatus can be adjusted to feed fuel and air in the correct proportions and to adjust the quantities in proportion to the load. The fireman is not required to make adjustments for each small change in load or steam pressure and can devote his individual attention to the fires. Irregularities caused by varying quality of coal or by clinker formations are then more quickly and easily corrected and better results naturally follow. Each adjustment by the automatic apparatus is made at the same time on all boilers and a greater degree of uniformity results.

Automatic apparatus must have certain features of construction and operation if it is to give satisfactory results. The plant can continue to operate with the combustion control equipment out of service, and in case of trouble it will not receive the attention that would be given a feed pump or draft fan. When it is out of service, it is useless and it is therefore necessary that only the best and simplest design be adopted and the workmanship should be of the best. Continuous operation with freedom from mechanical complication is necessary regardless of first cost. Operating characteristics are equally important. The apparatus should respond to each change in load by an amount proportional to the load change and it must do the same thing every time for the same change. The extent of adjustment for a given change must be adjustable because the load variations in one plant may be entirely different from those in another plant and it must be possible to get good results in both plants.

Not many years ago combustion control was supposed to require only something to turn things on when the steam pressure dropped a few pounds and shut them off when the pressure went up again. Such control often increases the coal bill in order to hold a uniform steam pressure. Combustion control is now understood to require the graduated adjustment of fuel and air supply in the correct proportion to each other and both in proportion to small changes in load. The best proof that such control results in worth-while savings is to be

*Chief Engineer, The Hagan Corporation.

found in the hundreds of plants that installed such equipment and where the records conclusively prove the savings effected. In one strictly modern plant, records comparing the best hand operation with automatic control showed a saving over hand control of 5½ per cent in spite of the fact that special efforts were made to secure the best hand control with the aid of draft gages, flow meters, and gas analyzing apparatus. Records from a large number of plants, both large and small, show savings from 4 to 5 per cent in the plants where the hand operation was of the best, to over 20 per cent where load conditions were severe and the hand regulation had not been done intelligently.

Recently a consulting engineer was retained by a manufacturing plant where the coal cost represented a substantial part of the total operating cost. It was explained to him that the coal bill must be reduced with the present equipment or a new plant built. He made a careful study of the entire situation and decided that the present equipment was good for 5 yr. more service and that in that length of time enough money could be saved by the right system of automatic combustion control to pay the entire cost of rebuilding the plant.

For the purpose of illustration, the following typical installations might be cited.

In a plant consisting of 1600 boiler hp., equipped with type "E" stokers, they were having serious trouble with the burning out of boiler tubes and brickwork and with the maintenance of forced draft equipment, while the chimney constituted serious smoke nuisance. These difficulties were all overcome by the application of automatic combustion control, and the fuel bill was reduced by $16,000 a year.

In a plant consisting of 3000 boiler hp., equipped with multiple retort underfeed stokers, a test consisting of one week's operation with the best hand control, was run. During this time data were kept from which it was determined that the automatic control increased the overall efficiency of the plant by over 5 per cent over that which had been obtained the previous week under test conditions with hand control.

Improving Combustion in a Hand-Fired Plant

Installation of Mixing Arches, Adopting Improved Methods of Draft Control and Firing, Enable Use of Bituminous Coal Without Smoke Production. By A. R. Mumford*

DUE to some simple changes made in the furnace and firing methods employed in a hand-fired return-tubular boiler plant, the cost of producing 1000 lb. of steam was reduced from $0.5287 to $0.3540 according to the report of an investigation recently conducted by the U. S. Bureau of Mines.

Ordinary return-tubular type boilers were employed, these being 18 ft. long and 56 in. in diameter, set 27 in. above the grates which were 6 ft. deep and 5 ft. wide. Due to the crowded combustion space, smoke and incomplete combustion resulted when bituminous coal was used as fuel. The space between the bridgewall and the shell of the boiler was only 5 in., while that over the floor of the combustion chamber was 20 in. Owing to the local smoke regulations, pea size anthracite was burned during the greater part of the day, bituminous coal being burned only at night when the demand for steam was somewhat less than during the day and the smoke could not be seen.

Before bituminous coal could be used continuously it was necessary so to reconstruct the furnace that combustion of the gases would be completed before they left the furnace. In the original setting the combustion space was too small and no mixing device was provided in the path of the gases. These constituted the principal difficulties.

On account of mechanical difficulties involving excessive cost, it was not feasible to alter the relative position of the grates. The combustion chamber beyond the bridgewall, however, had been built up from a concrete floor with filling and a layer of loosely laid brick, and by removing this filling the distance of the floor from the shell of the boiler was increased from 20 to 30 in.

By the installation of two semi-obstructing arches, one over the bridgewall and one in the combustion chamber, proper mixture of gases was obtained. The vertical distance between the shell of the boiler and the top of the bridgewall was only 5 in. in the original installation, and this distance had to be increased to 10 in. before an arch could be placed over the bridgewall. This arch over the bridgewall closed off the former opening around the shell of the boiler and reduced the area available for gas passage from 5.6 sq. ft. to 1.7 sq. ft. The arch was extended for 3 ft. from the front edge of the bridgewall in the directions of gas flow, to provide hot fire-brick surface for the ignition of any combustible gas-air mixture not previously ignited. The reduction in area caused a temporary increase in velocity, which resulted in a turbulent flow, so that mixing was greatly assisted. The increase in velocity and the mixing action were accomplished at the expense of the available draft, and this is the determining factor that governs the extent to which such obstructions may be employed.

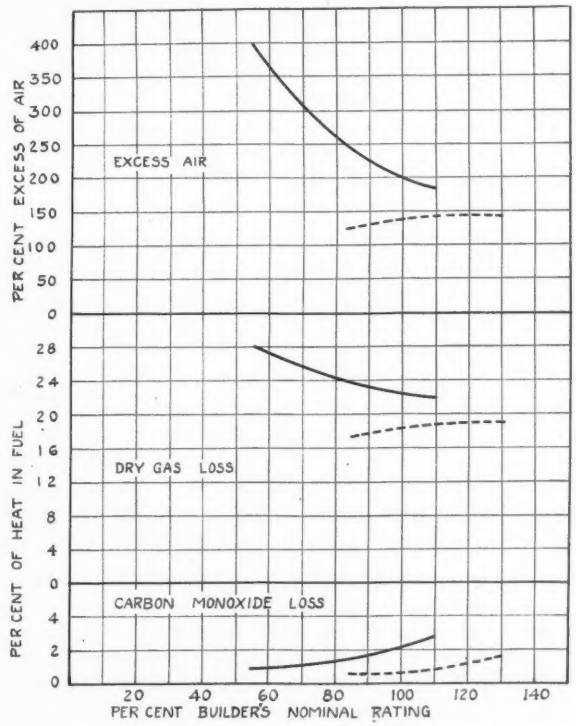
Just beyond the bridgewall the area available for gas passage is 12 sq. ft., an increase of 10.3 sq. ft. over that available above the bridgewall. This increase in area considerably reduces the velocity of the mixture of gases which have come through the restricted area and so gives them a longer time to burn. The deflection arch in the combustion chamber was of single-span construction, extending from the floor to the boiler, and leaving only a semi-circular opening 4.15 sq. ft. in area next to the floor of the combustion chamber. This deflection arch caused the gas stream to turn towards the floor of the combustion chamber, and further assisted in mixing by causing a second contraction, increase in velocity, and expansion of the gas stream. These changes in furnace arrangement in connection with the introduction of an improved method of firing permitted the substi-

*Assistant Fuel Engineer, Bureau of Mines.

tution of bituminous coal for anthracite at a reduction of approximately $3.00 per ton in delivered price.

Original and Modified Method of Control of Boilers

It was found during the course of tests that the operation of the boilers was left entirely to the firemen, as long as steam pressure was maintained above 100 lb. and below the blowing off point of approximately 110 lb. This method resulted in irregular firing and increased fuel losses because the firemen added fuel or worked the fires only when the steam pressure was decreasing. The dampers on all of the boilers under fire were always wide open, and if the steam pressure rose toward the blowoff point the firemen reduced the rate of combustion by closing the ash-pit doors, and if the steam pressure continued to rise the rate of combustion was further reduced by opening the fire doors.



DRAFT CONTROL BY MEANS OF ASH-PIT DOOR GIVES GREATER LOSSES THAN BY MEANS OF DAMPER

Evils resulting from the closing of the ash-pit doors are caused by the increase in the draft throughout the boiler. When the ash-pit doors are open the draft available at the damper of each boiler is used to draw air into the ash pit and through the grates and fuel bed, thereby burning the coal; to move the products of combustion through the boilers; and to draw air into the setting through any openings in the fire doors or cracks in the brickwork or boiler casing. This influx of air through cracks in the brick work or boiler casing is objectionable, and should be prevented by keeping the brickwork and casing air tight.

When the ash-pit doors are closed the amount of air entering under the grates is greatly decreased, thereby decreasing the rate of combustion and the quantity of the products of combustion flowing through the boiler. On the other hand, closing the ash-pit door increases the draft throughout the setting and thereby increases the infiltration of cold air into the setting through cracks in the brickwork or openings in the furnace doors, and thus cools the products of combustion and increases the flue gas losses. When the amount of air passing up through the grates and fuel bed is reduced, the grate bars and the ash resting on them become overheated by conduction of heat from the fuel bed. This overheating melts the ash, forming clinker, aud causes the gratebars to burn.

Opening the fire doors to reduce further the rate of combustion not only results in the same evils that result from the closing of the ash-pit doors, but in addition cools the boiler unequally and puts a local stress on the boiler which, especially with fire-tube boilers, increases the wear and repairs necessary on boiler and brick work. The use of this method of controlling the rate of combustion is brought about by irregular intervals between firings, varying quantities fired at each firing, and inaccessible dampers.

In the accompanying chart the flue gas losses and excess air plotted against boiler rating for two methods of boiler control. The solid curves show the variation in gas losses and excess air when the boiler was controlled by the ash-pit doors and the dotted curves show the variation in gas losses and excess air when the boiler was controlled by the damper.

Original and Modified Method of Firing

Perhaps the best criterion which can be used to judge the practicability of a firing method, from the viewpoint of the fireman, is the amount of work he must do to produce a given amount of steam. If a new method requires more actual work on the part of a fireman, it is likely that the method will be opposed, but if the fireman can be convinced that the new method requires no more work, and whether a fireman had to perform more actual work per 1000 lb. of steam produced when he fired according to an improved method than when he fired without any attempt at regularity and without care, a record was kept on each test of the time spent on the various operations for each of the tests made.

Table I, Column 1, gives the summary of the record of work done by the fireman on a test with anthracite; column 2 gives the record for a test with bituminous coal under original operating conditions, and Column 3 gives the record for a test with bituminous coal under the improved operating conditions. Table II gives a summary of the total time spent by the fireman on each of the various operations concerned with the fires.

Tests 1 to 5, inclusive, recorded in Table II, represent former plant operation, and Tests 8 to 10, inclusive, represent test conditions with a different method of firing in use.

With anthracite the average work in minutes required of a fireman per 1000 lb. of steam produced is 2.69 min.; with bituminous coal, under former plant operation, 1.98 min.; and with bituminous coal, with the new firing method, 1.94 min.

By adopting as the improved firing method, the alternate system of firing, only one-half of the grate surface is charged with green fuel at any one time, and the

remaining half is left covered with a bed of freely burning incandescent coke from the preceding firing. In this way the fluctuation in furnace temperature is reduced and a temperature high enough to ignite the mixture of combustible gases and air, in the furnace, is maintained.

Efficiencies and Costs Before and After Modifications

In order to determine the performance of the plant both before and after the modifications in the setting and control were introduced, a series of tests at different rates of evaporation per hour were made. Six tests, three with anthracite and three with bituminous coal, were made under the original conditions. After

TABLE I—ORIGINAL AND IMPROVED FIRING CONDITIONS WITH ANTHRACITE AND BITUMINOUS COAL

	1 Original Anthracite	2 Original Bituminous*	3 Improved Bituminous†
Total minutes spent on firing	33.08 min.	31.75 min.	18.05 min.
Average minutes spent per firing	0.81 "	0.86 "	0.44 "
Maximum minutes spent on one firing	1.50 "	1.67 "	1.05 "
Minimum minutes spent on one firing	0.50 "	0.42 "	0.33 "
Average interval between successive firings	14.16 "	17.30 "	17.53 "
Maximum interval between successive firings	25.34 "	36.42 "	29.00 "
Minimum interval between successive firings	6.08 "	1.92 "	15.00 "
Average coal fired per firing	104.5 lb.	124.0 lb.	86.25 lb.
Maximum coal fired on one firing	168.0 "	315.0 "	229.3 "
Minimum coal fired on one firing	72.0 "	60.0 "	76.4 "
Total minutes spent on cleaning	42.25 min.	20.58 min.	6.33 min.
Total minutes spent on barring or levelling		17.75 "	30.16 "
Average interval between successive barrings or levelings.		52.87 "	20.32 "
Maximum interval between successive barrings or levelings.		92.00 "	78.00 "
Minimum interval between successive barrings or levelings.		70.08 "	15.00 "
Total time spent on boiler by fireman in 12 hours	75.33 "		58.04 "
Average time required of fireman to produce 1000 lb. of steam	2.75 "	1.88 "	1.97 "

* Cleaning began 5:51:40; lasted 20 min. 35 sec.
† Hooked fires 10:49; duration 117 sec., and at 2:30 duration 93 sec.
Barred fires 6:02; duration 51 sec.
6:17; duration 65 sec.
Cleaned fires 5:35; duration 6 min. 20 sec.

the conditions had been modified three more tests were run with bituminous coal to determine the actual improvement in efficiency.

Table III presents the heat balances of the whole series of tests. Tests 1, 2 and 3 represent plant operation with anthracite; tests 4, 5 and 6 represent plant operation with bituminous coal; and Tests 8, 9 and 10 represent modified operation with bituminous coal.

Of the results obtained with anthracite, the principal features are shown by the variation in efficiency, dry-gas loss, and ash-pit refuse loss, with rating. The efficiency and dry-gas losses decrease as the rating increases, while the loss in the ashpit refuse tends to increase with the rating.

Under the original operating conditions with bituminous coal the efficiency increased with the increase of rating as shown in Tests 4, 5 and 6. This increase in efficiency with increase in rating is accompanied by a reduction in dry-gas losses, and a reduction in the losses unaccounted for. The CO loss increases, as would be expected, as the rate of burning coal increases.

Under the modified operating conditions with bituminous coal the efficiency increases with a decrease in rating. The increase in efficiency is accompanied by a decrease in dry-gas losses, and a decrease in loss due to carbon monoxide in the flue gases. The decrease in dry-gas losses with decrease in rating, just the reverse

TABLE II—TIME SPENT BY FIREMAN IN VARIOUS OPERATIONS ON TEST BOILER

Test No.	Rate of Working Boiler Per cent	Firing Min.	Cleaning Min.	Levelling Min.	Barring Min.	Total Time 12-hr. test Min.	Time per 1000 lb. steam Min.	Kind of Fuel
1	71	23.34	35.92	.....	.....	59.26	2.38	Anthracite
2	79	33.08	42.25	.....	.....	75.33	2.75	do
3	63	24.00	40.75	.....	.....	64.75	2.94	do
4	107	31.75	20.58	.....	17.75	70.08	1.88	Bituminous
5	81	26.08	16.67	.....	15.67	58.42	2.08	do
8	125	25.50	12.67	24.51	17.75	80.43	1.87	do
9	99	22.00	6.20	27.43	12.68	68.31	1.97	do
10	85	18.05	6.33	28.23 3.50*	1.93	58.04	1.97	do

*Hooking

of the trend of the dry-gas losses under the original conditions, is brought about by the decrease in pressure difference between the inside and the outside of the setting as the damper is closed.

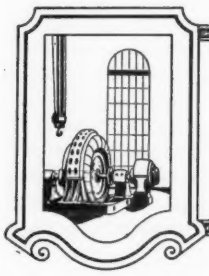
That the efficiency increases with a decrease in rating under the modified operating conditions is an especially desirable condition because of the low average rate of working the boilers in the plant under consideration. The average rate of working the boilers was estimated to be 75 per cent of builder's nominating rating. Thus the gain in efficiency due to modifying the conditions

TABLE III—PERFORMANCE FIGURES BEFORE AND AFTER MODIFICATIONS

	Before Modification						After Modification		
Number of trial	1	2	3	4	5	6	8	9	10
Kind of coal	Anthracite			Bituminous			Bituminous		
Per cent of builder's rating	71	79	63	107	81	56	125	90	85
Heat absorbed by water %	57.9	55.7	58.9	66.0	61.0	59.0	66.5	65.7	69.0
Heat carried away by dry gases %	18.9	18.4	20.1	22.1	24.0	27.7	19.0	18.5	17.4
Heat carried away by CO in dry gases %	0.0	0.0	0.0	2.8	1.0	1.3	1.4	0.7	0.7
Heat carried away by steam in flue gases %	2.3	2.3	2.3	3.7	3.6	3.5	3.5	3.5	3.5
Heat lost in ash pit refuse %	14.4	16.2	14.7	2.4	4.8	2.6	3.1	5.3	4.1
Heat unaccounted for %	6.5	7.4	4.0	3.0	5.6	5.9	6.5	6.3	5.3
Total	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
Evaporation per lb. coal lb.	6.61	6.36	6.73	8.70	8.05	7.78	8.82	8.71	9.15
Coal per 1000 lb. steam lb.	151.3	157.2	148.6	114.9	124.2	128.5	113.4	114.8	109.3
Cost of coal per 1000 lb. steam $	.6943	.7215	.6820	.3775	.4061	.4222	.3726	.3772	.3591

was 13.2 per cent over the original conditions with anthracite coal, and approximately 9 per cent over the original conditions with bituminous coal.

Cost of coal per 1000 lb. of steam under the original operating conditions at the average rate of boiler working was $0.7050 with anthracite and $0.4225 with bituminous coal. After modifying the conditions the cost of bituminous coal per 1000 lb. of steam was $0.3540.



ELECTRICAL MACHINERY FOR LIGHT AND POWER

Alternating Current Transmission Lines

PART II. THE GROUNDED NEUTRAL, STAR DELTA TRANSFORMER CONNECTIONS, EQUIVALENT Y METHOD OF CALCULATING 3-PHASE CIRCUITS. BY E. K. McDOWELL*

IN CONTINUING the discussion of three-phase circuits which was started in the March 15 issue, the next important consideration which demands attention is the subject of the grounded neutral.

GROUNDED NEUTRAL

CONSIDER THE case of a three-wire transmission circuit supplied with 3-phase current from three Y-connected windings, which may be either armature coils of a three-phase generator or three transformer phase-windings; these windings being represented by the coils marked A, B and C in the accompanying sketch. If, then, the neutral point N of this Y-connection be permanently connected to ground, the arrangement is known as a "Grounded Neutral."

Perhaps the most important effect of the grounded neutral is that the e.m.f., between any phase and ground, that can be impressed on the insulation is limited to 58 per cent of the line e.m.f., or, in other words, to E ÷ 1.73 where E is the e.m.f. between phases. Otherwise (supposing the neutral ground G to be omitted) an accidental ground—say on phase 1, as at M on the sketch—impresses full line voltage E, on an insulator or on the insulation, as at point K; between phase 3 and ground.

On extensive circuits, particularly of high-voltage transmission, an accidental ground (as at M) would tend to set up high voltage surges and disturbances in the line if the neutral were not grounded. These surges would tend to be oscillatory in character and would thereby cause the line e.m.f. to be raised to excessive values, greatly exceeding E. This excessive voltage would be impressed, say at any critical point in the insulation as at K, between the conductor 3 and ground. Such oscillations, or surges, are characteristic of extensive ungrounded transmission circuits, and are propagated over the whole system; frequently causing puncturing and breaking-down of insulation at points far remote from the original accidental ground.

If, however, the neutral of the circuit be grounded, as at G in the sketch, most of such disturbances will merely result in an excessive current with only a comparatively small initial surge, or oscillation; after which the e.m.f. to ground (as at K) remains constant at E/1.73 v. Generally then the only adverse result will be that the excessive current will open the circuit-breakers and disconnect the circuit from the system; thus causing a temporary interruption of service.

*Chief Engineer, Donora Steel Works, American Steel & Wire Co.

Ungrounded circuits will usually be delta-connected (except in the case of three-phase, four-wire circuits, previously described) since an ungrounded Y-connected three-wire circuit has an unstable neutral; and by reason of this, an excessive voltage strain on one phase is possible under certain irregular circuit conditions.

EXTENT OF USE

GROUNDED NEUTRAL circuits are encountered, at present, mainly in connection with public-service systems;

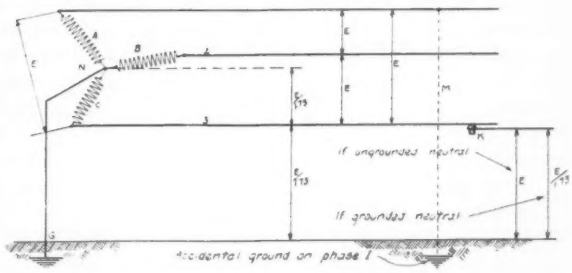


DIAGRAM OF A 3-PHASE, 3-WIRE TRANSMISSION LINE WITH GROUNDED NEUTRAL

in particular on relatively extensive and high-voltage main transmission lines that are many miles in length.

Steel plant practice has not, so far, favored the use of grounded neutral systems in connection with steel mill central power installations. This is largely due to fear of frequent delays as a result of accidental grounds that would not ordinarily, on an ungrounded system, involve interruptions of service.

Growth that has taken place in many such installations, however, has frequently involved the addition of transmission lines of considerable length; the whole system being, in many cases, comparable in extent with a fairly large public-service installation. In such instances, conditions, at least regarding the main transmission lines, are not dissimilar to those obtaining on public-service systems. Accordingly there is reason to anticipate a future tendency to consider seriously the use of grounded neutral, at least on the longer high-voltage transmission lines, in connection with large steel mill central power systems.

Grounded neutral in general, then, is of advantage as a means of practically eliminating high-voltage surges and disturbances that are characteristic of ungrounded systems. It is more advantageous on larger high-volt-

age systems and longer transmission lines than on smaller systems; but it is not possible to give definite limits above which it is advisable to make a system grounded neutral. It has the disadvantage that an accidental ground causes a definite short-circuit on one phase, thus disconnecting the circuit and entailing an interruption of service.

Star-Delta Transformer Connections

Star-delta transformer connections are generally referred to more specifically as either delta-star, if the receiving side of the transformer bank is delta-connected and the delivering side is star (Y) connected; or as star-delta for the reverse arrangement. Transformer connections of this character are used extensively on public-service systems for interconnections, of various sorts, between Y-connected circuits or transmission lines and delta-connected circuits. Two common uses are (1) where a Y-connected grounded-neutral high-voltage transmission line is supplied, from generators or station bus, through a delta-star transformer bank; and (2) in connection with three-phase, four-wire distribution circuits, as described in the March 15 issue.

In connection with the first-mentioned class of installations, the neutral of the Y-connected secondary (or high-voltage) side of the raising, or supply, transformers will be grounded; but the transformers at the receiving end of the transmission line may be either Y- or delta-connected to the circuit; depending more or less on conditions at the receiving end. In either case, the line will have the properties and advantages, previously described, of a Y-connected grounded-neutral circuit; which properties obtain irrespective of the character of the receiving-end transformer connection.

In general it is considered that one grounded neutral on a circuit gives sufficient protection in the way of eliminating high-voltage surges and disturbances; although frequently an important main high-voltage transmission line will be Y-connected at both sending and receiving ends; to (say) delta-Y raising transformers and Y-delta lowering transformers respectively. In such case the neutrals of both Y-connections will be grounded; and, in general, where a Y-connection is used, except in a three-phase, four-wire circuit, the neutral is always grounded in order to avoid the unstable neutral condition previously referred to.

Phase displacement in a star-delta (or delta-star) transformer connection is an effect that has to be considered occasionally; mainly when two or more circuits involving such connections have to be operated in parallel. The matter is thus somewhat outside the scope of this article; but is given limited mention here as a matter of general information.

The effect referred to is, considering a Y-delta transformer connection, for example; that the e.m.f.'s and current-amps in each of the three phase-wires connected to the delta (delivering) side of the transformer group will be 30 deg. out of phase with the e.m.f.'s and current-amps (respectively) in the corresponding phase-wires connected to the Y, or receiving, side of the transformers. This phase-displacement matter will probably require consideration only in the case of tie-lines, or similar conditions, where two or more circuits supplied from a common bus (or main transmission line) have to feed into one system or network; thus operating in parallel. In such case, if only one of the two circuits has Y-delta transformers, there will have to be an even number of these (e. g., delta-Y and a Y-delta) on that circuit in order to operate the two circuits in parallel. Then the phase displacement is neutralized: since in a Y-delta connection the phase displacement is of opposite sense, regarding phase angle, to the displacement in a delta-Y transformer bank. If both circuits have transformer groups of this character there will have to be either an even number or an odd number of transformations on each of the two circuits.

Equivalent Y Method of Calculation for 3-Phase Circuits

This has to do with a certain procedure that it is convenient and advisable to follow, in the figuring and analysis of all three-phase circuits, on account of the special phase-relations that, as previously shown, obtain in all such circuits.

It will be seen, in later sections, that the method of figuring the drop in voltage in a single-phase a.c. circuit is similar to the procedure for d.c. circuits; being based on the same fundamental equation $E_1 = I R$. One-half of the total voltage-drop takes place in the outgoing wire and one-half in the return wire; but the total drop is the sum of these halves since the currents (and e.m.f.'s) in both wires are in phase with each other. In the case of three-phase circuits, however, the e.m.f. in any one conductor is 120 deg. out of phase with the e.m.f.'s in each of the other conductors. Therefore the voltage drops in individual phase-wires cannot be added arithmetically to obtain the total voltage drop between conductors, but must be added vectorially.

The "voltage drops" in any two of the three conductors are out of phase with each other by the same angle as are the line e.m.f.'s and currents in the respective phase-wires; i.e., by 120 deg. Accordingly, if E_{1-0} = the voltage drop in one conductor, the voltage drop between conductors will be the vector sum of the two e.m.f.'s E_{1-0} that are 120 deg. apart in phase; i.e., $E_1 = \sqrt{3}\ E_{1-0}$ as can be shown by a vector diagram similar to sketch on page 320 of the March 15 issue.

It is seen that the ratio of E_{1-0} to E_1 is the same as the ratio of the e.m.f.-to-neutral ($E \div \sqrt{3}$) to the e.m.f. between main conductors (E) in a Y-connected circuit. The voltage drop in one conductor (E_{1-0}) is, therefore, commonly referred to as the "drop to neutral"; regardless of whether the circuit in question is Y-connected or delta-connected. These conditions are most conveniently met by the use of the so-called equivalent-Y method for calculation of three-phase circuits.

This method can best be considered as a rule, or procedure, which embodies the most convenient method of applying the foregoing conditions to the practical calculation of any three-phase circuit. It can be used in connection with either Y-connected or delta-connected circuits; the procedure being identical in either case. The method can be outlined about as follows:

Assume one-third of the total power as transmitted over one of the three conductors, this conductor then being figured as a single-phase line with an assumed neutral (or ground) return of zero resistance and reactance; and with an assumed line e.m.f. corresponding to the e.m.f. to neutral of the three-phase circuit.

For example, the e.m.f. of the assumed single-phase line is $E \div 1.73$, where E is the e.m.f. between main conductors of the circuit; whether Y- or delta-connected.

The current-amps for the assumed line would be determined, in applying the method, as $I = P/3 \div E/1.73$; which reduces to $I = \frac{P}{1.73E}$ ..... (7).

This, as might be expected, is another form of equation (6), which appeared on page 322 of the March 15 issue; and is the equation that is generally used for determining current per phase of any three-phase circuit; whether Y- or delta-connected.

Note that the method, when used in calculating a delta-connected circuit, is applied just as if the circuit were Y-connected. That is, an "imaginary" neutral is assumed; since a delta-connected circuit has (strictly speaking) no neutral.

Line voltage-drop to neutral, E_{1-0}, is determined by the same methods as for a single-phase circuit: except that the one-way length of line, L, is used as a multiplier in connection with resistance (or reactance) per unit length to obtain the total resistance (or reactance) used in the equation, $E_0 = I R$ (or $E_x = IX$), from which the said voltage-drop is then determinend.

A line voltage-drop E_{1-0} is thus calculated for the assumed single-phase circuit, or in other words for one conductor of the three-phase circuit, which is the drop to neutral; because the resistance (or reactance, if this is what is being considered) from which this voltage-drop was figured was that of one conductor, only, of the assumed single-phase line. Finally, the actual voltage-drop between any two conductors of the three-phase circuit is calculated; and is equal to $1.73\,E_{1-0}$. Or, if preferred, the e.m.f. to neutral at the sending-end of the circuit can be figured; and will be equal to $E/1.73 + E_{1-0}$; and then the sending-end e.m.f. between any two phases (of the three-phase line) will be $(E/1.73 + E_{1-0}) \times 1.73$. The procedure is exactly the same, and results will be correct to the same degree, when applying this method to a delta-connected circuit as in the case of a Y-connected circuit.

This method of calculation of three-phase circuits is quite generally used in practice, and is readily adaptable to the various conditions that arise in connection with different arrangements of transmission systems. Although fairly simple in application, it is rather difficult to explain except in connection with the preceding matter in this section regarding Y-connections, etc.

It is especially important that the reader should understand the theoretical basis of this Equivalent-Y method, and be satisfied of the correctness thereof. This is essential if it is to be used with confidence in calculations embracing varied circuit conditions. Certain points, referred to incidentally in the preceding explanation, will be developed in more detail in subsequent articles of this series.

Compensated Direct Current Motors

WHERE GOOD INHERENT SPEED REGULATING CHARACTERISTICS ARE REQUIRED, THE COMPENSATED D. C. MOTOR IS HIGHLY SATISFACTORY. BY H. E. STOKES

IN ANY direct current machine, the current in the armature tends to set up a magnetomotive force at right angles to the field set up by the main field poles. This may be seen from Fig. 1, which represents a two-pole machine with current in the armature. The current enters at the brush and circulates around the armature core so that north and south poles are produced at the center of the space between the main poles. The result of this is to produce cross-magnetism in the main pole faces, as shown in Fig. 2. This cross-magnetization strengthens the magnetic flux at the main pole tips *a a*, and weakens it at *b b;* the flux entering the armature from the main pole faces is similarly strengthened and weakened toward the pole tips and thus the armature conductors during the passage under the pole face are cutting a magnetic field of low intensity at one pole tip and of higher intensity at the other. Figure 3 illustrates the flux density under the pole faces.

Since the voltage induced in the armature conductors is proportional to the flux density of the magnetic field cut at any instant it follows that the distribution of voltage on the armature coils, and the corresponding commutator bars, is similar to the picture of the flux distribution shown in Fig. 3.

When an uncompensated direct-current motor or generator is running at light load, the terminal voltage is distributed equally over that portion of the commutator corresponding to the armature coils under the pole faces. With load on the machine the voltage on the commutator bars is boosted at the points corresponding to the points of increased flux under the pole face. Since there is a well defined limit to the voltage between the commutator bars, it will be seen that it might become necessary in certain cases to design a freak machine in order to keep the voltage between commutator bars down to a safe limit; the alternative is to use a compensating winding.

A compensating winding is a winding lying in the pole face parallel to the armature coils and which is proportional so that the ampere-turns of the pole face winding are equal to those in the armature under the pole face, but the current flows in the opposite direction. One effect of a compensating winding is therefore to neutralize the distorting influence of the armature upon the main pole flux and to effect an equal distribution of voltage on the commutator under the pole face.

In an uncompensated motor whose speed is varied by field control, the maximum voltage between the commutator bars is very seriously increased by armature distortion at the maximum speeds. This is because the armature distortion tends to hold the flux nearly constant in value at one tip of the main pole, over the whole speed range, while the speed and velocity of cutting the flux by the armature conductors may be several times higher than normal. As a rough rule, it may be said that the ratio of the maximum to the normal voltage between commutator bars of a non-compensated motor, at a given running speed, is proportional to the ratio of the running speed to the full field speed. Thus, where the full field speed is 400 r.p.m., the maximum voltage between commutator bars at 1200 r.p.m. will be approximately three times as high as at 400 r.p.m.

Another method of predicting more accurately the maximum voltage between commutator bars of an uncompensated direct-current machine is shown in Fig. 4,

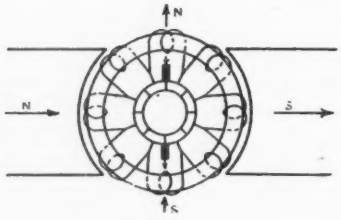


FIG. 1

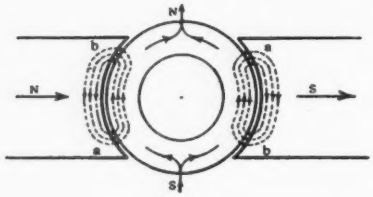


FIG. 2

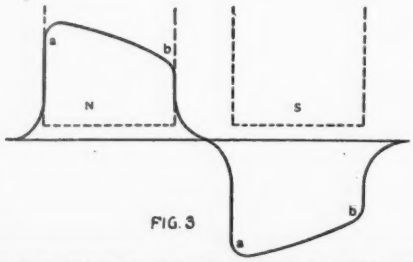


FIG. 3

FIG. 1. MAGNETOMOTIVE-FORCE SET UP BY THE ARMATURE CURRENT OF A TWO-POLE MACHINE

FIG. 2. CROSS-MAGNETISM PRODUCED IN MAIN POLE FACES BY ARMATURE CURRENT

FIG. 3. FLUX DENSITY UNDER THE POLE FACES

which shows the saturation curve of a direct-current motor having a full-field speed of 250 r.p.m. and a speed range of 250 to 750 r.p.m. by field control. At 250 r.p.m., the flux per pole is 7×10^6, while for 750 r.p.m. the required flux is one-third this value. Curve O X represents the ampere-turns per pole required for the air gap. The horizontal distance between the curves OX and OY gives the ampere-turns for the armature teeth and the armature core. The horizontal distance between the curves OY and OZ represents the ampere-turns required for the main poles and magnet frame. The curve OZ shows the total ampere-turns per pole required for the whole magnetic circuit for any desired flux per pole.

An inspection of Fig. 2 shows that the cross-magnetization flux produced by the armature ampere-turns takes a path through the armature core, armature teeth, air gap and main pole face and back into the armature core through the air gap at the other tip of the main pole face. Since the main pole ampere-turns are tending to force the flux uniformly across the whole face of the main pole into the armature, it is evident that the armature ampere-turns are bucking the main pole ampere-turns at one tip of a main pole and boosting it at the other. At the center of the main pole face the bucking and boosting effect is zero.

At a speed of 250 r.p.m. corresponding to a flux of 7.0×10^6, the main pole ampere-turns forcing the flux through the air gap, the armature teeth and core are represented in Fig. 4 by the length BC or about 5400 ampere-turns per pole. Now, assuming the armature ampere-turns under the main pole face, which produce armature distortion at the maximum peak load which the motor has to carry, amount to, say, 7000 ampere-turns, then setting off 7000 ampere-turns horizontally from point C gives the point D. We now have BD ampere-turns forcing a flux through the air gap into the armature at one pole tip. Draw a vertical line from point D hitting the curve OY at E. There is now a flux density proportional to EF or 9.1×10^6 entering the armature from the air gap at the boosted pole tip. Knowing this value, it is possible to calculate the maximum volts between commutator bars corresponding to the armature conductors at the pole tip boosted by the armature ampere-turns.

If there are 120 commutator bars in a four-pole motor operating at 250 v., there would be 30 commutator bars per pole. The average voltage between commutator bars would therefore be $\frac{250}{30} = 8.3$ v.

Since only that part of the armature under the pole face is cutting magnetic flux, the portion of the armature between adjacent pole faces is idle and has practically zero voltage between the commutator bars. In calculating the actual voltage between commutator bars we

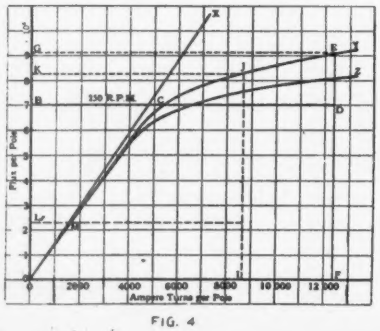


FIG. 4

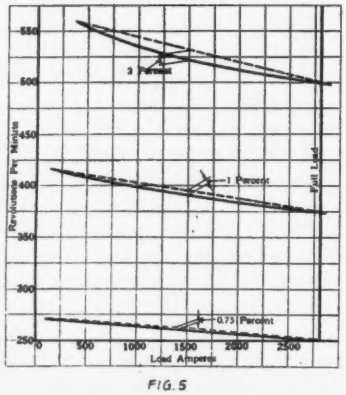


FIG. 5

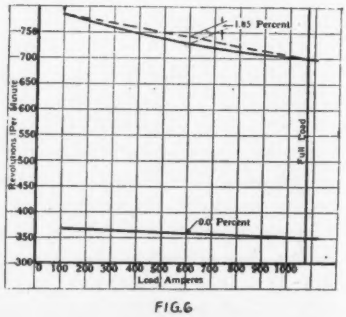


FIG. 6

FIG. 4. SATURATION CURVES OF AN ADJUSTABLE SPEED DIRECT CURRENT MOTOR

FIGS. 5 AND 6. TYPICAL SPEED CURVES OF AN 800-HP., 600-V. COMPENSATING MOTOR

have therefore to allow for this idle portion and the actual voltage between bars under the pole face becomes $\frac{8.3}{0.7} = 11.8$ v., where 0.7 is the ratio of the pole face to the pole pitch. This is the voltage between commutator bars at light load without armature distortion. To obtain the maximum voltage between bars at the peak load at 250 r.p.m., this value must be multiplied by the ratio of $\frac{EF}{BO} = \frac{9.1}{7.0} = 1.3$. This gives $11.8 \times 1.3 = 15.3$ v.

By carrying out the same construction at 750 r.p.m., corresponding to a flux of 2.3×10^6, we obtain a flux at the boosted pole tip of OK where the flux at light load was only OL or an increase of flux due to the peak load of $\frac{KO}{LO} = \frac{8.3}{2.3} = 3.6$ times the light load flux. Since the voltage between commutator bars under the pole face at light load is 11.8 v., the voltage between bars at the peak load becomes $11.8 \times 3.6 = 42.5$ v.

Thus the effect of speeding up the motor from 250 to 750 r.p.m. has been to increase the maximum voltage between commutator bars from 15.3 to 42.5 v. The addition of a compensating winding to this motor would have the effect of eliminating the armature distortion and maintaining the maximum voltage between bars at a value of 15.3 v. over the entire speed range of the motor.

As stated previously, it is unsafe to exceed a certain maximum value of voltage between the commutator bars, as to do so may cause flashing or bucking-over on the commutator between brush arms with serious results to the commutator and brush rigging. A compensating winding operates to prevent bucking-over by preventing the high maximum voltage between commutator bars just as a commutating-pole winding prevents sparking on the commutator.

Influence on Overload Capacity of a Compensating Winding

In a compensated motor or generator the sum of the compensating and commutating-pole ampere-turns is about equal to the commutating-pole ampere-turns of a similar non-compensated motor or generator, the main difference being that part of the commutating-pole windings are opened out and laid in slots in the main pole face. This arrangement has a very important bearing on the overload capacity of a compensated machine, in that ampere-turns on the compensating winding, which are approximately equal in value to the commutating pole ampere-turns, do not produce any commutating pole leakage. A reduction of the leakage flux, for the same load, results in a decrease in the commutating pole flux density and therefore permits a greater peak load to be carried by the machine. The importance of this aspect of the case will be clear when it is stated that the commutating pole leakage flux is, in some cases, three to four times the value of the useful flux for commutation, and in such cases three-fourths to four-fifths of the commutating pole has to be provided to carry the leakage flux. The value of a compensating winding which cuts the leakage flux in two, and leaves five-eighths of the commutating pole, instead of one-fourth,

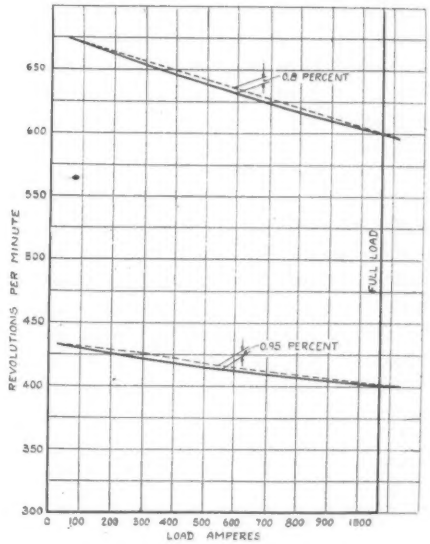


FIG. 7. SPEED CURVES OF A 350-HP., 250-V. COMPENSATED MOTOR

available for useful commutating flux, can readily be appreciated.

Compensated machines have been built which have carried momentary peaks of six to ten times full-load current, and even a dead short-circuit near the terminals of the machine corresponding to about eighteen times full load has been carried in some instances without causing a buck over.

Certain classes of motor drive require very close speed regulation between light load and the loaded condition. Paper machines are frequently operated at high surface speeds when making light grades of paper and unless the motor has good speed regulation a change of load due to an adjustment of pressure on the rolls of the paper press or for other reasons may cause a break in the paper and a consequent loss of time and production.

For certain types of steel mill drive, good speed regulation characteristics are of considerable importance in obtaining successful operation of the mill. Hot strip mills are sometimes arranged with independent motor-driven rolls in tandem and are operated at high rolling

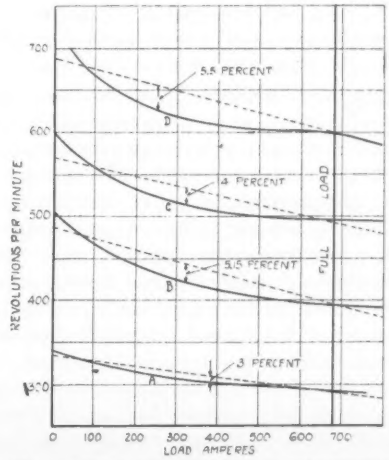


FIG. 8. TYPICAL SPEED CURVES OF NON-COMPENSATED MOTOR

speeds without looping the strip; these mills also are required to operate over a wide speed range of sometimes more than two to one. The distance between rolls is usually only a few feet and with the high rolling speeds used, a small percentage change in speed between the separate motors may be enough to cause looping or stretching of the strip.

Satisfactory operation under these conditions demands good inherent speed regulation characteristics of the motors driving the rolls and the use of compensated direct-current motors has been found to afford the most satisfactory means of meeting these difficult conditions. Figures 5 and 6 show typical speed curves of compensated motors having speed ranges of two to one by field control. In these machines a certain drop in speed was desired from light load to full load, and the percentage departure of the speed curve from a straight line is very small over the whole speed range. Figure 7 shows speed curves of a compensated motor in which the speed range is obtained by voltage control of the generator, the generator voltage being held constant for each speed curve. These curves show very considerable improvement over the curves shown in Fig. 8, which are typical speed curves for a non-compensated direct-current motor.

There are many direct-current motor-driven steel mills operating successfully with non-compensated motors and everyone is, of course, familiar with numerous such cases. It should be distinctly understood that no attempt is being made in this article to disparage the value of non-compensated machines, which are entirely satisfactory for the majority of applications. Compensated motors are, however, desirable in mills having separately driven stands or trains, where looping is not feasible, and the finishing stands are delivering small section steels at a high rate of speed. The generators furnishing power for these motors are with advantage built with compensating windings, the voltage regulation curves of such generators being practically a straight line, so that with a change in load, the supply voltage is maintained at a constant value.

With reversing mill drives the frequent high peak load is a problem to the solution of which the compensating winding has contributed a large share. In rolling steels of small section, the tendency appears to be in the direction of separately driven stands which allow of greater flexibility in the matter of wear on the rolls, so that worn rolls can be retained longer; gears are also eliminated with a consequent reduction of mill friction. —Electric Journal.

Can Power Be Transmitted by Radio?

ALTHOUGH IMPROBABLE, A DISCUSSION OF THE POSSIBILITIES OF RADIO TRANSMISSION OF POWER IS INTERESTING

CAN POWER BE transmitted by radio? Will we, some day, be able to dispense with our wire transmission lines and use the ether of space as a medium for carrying the hundreds of millions of kilowatts that are needed to satisfy the demands of modern and future civilizations?

Because of the world-wide interest in radio telephony and telegraphy at the present time, these are logical questions, and it is not strange, therefore, that interest in them has been revived. We say "revived," because they are not new questions; ever since that memorable day in March, 1899, when Marconi succeeded in sending the first wireless message across the English Channel, men gifted with imaginative minds have speculated upon the possibility of transmitting energy from one place to another without the aid of wires or other tangible connecting medium. Can it be done?

It is highly improbable that power will ever be transmitted by radio, that is, as a commercial proposition, yet in view of our present knowledge of radio phenomena it cannot be said to be impossible. Power *can* and *is*, today, being transmitted by radio, but the quantities involved are so extremely minute that, except for the purpose of transmitting intelligence, they cannot be utilized. Every radio telegraph and telephone transmitting station in the world today sends out radio power but the amount of this power actually collected by the receiving station is so small as to be capable of being expressed only in terms of micro-watts. So from a purely physical standpoint, it must be admitted, power can be transmitted by radio; but as a practical proposition, it may be said to be impossible at the present time.

PRINCIPLES OF RADIO PHENOMENA

BEFORE GOING into a discussion of the future possibilities and the limiting factors of radio power transmission, it may be well, for the benefit of those unfamiliar with the subject, to explain, briefly, the principles involved in radio telegraphy.

Radio communication is effected through the agency of electro-magnetic waves set up in the ether. These waves are similar to light waves in every respect with the one exception that they are very much longer. Light waves, as is well known, are also waves in the ether; but instead of measuring them in hundreds or thousands of meters as we measure radio waves, we measure them in millionths of a centimeter. Visible light waves vary in length between $\frac{39}{1,000,000}$ and $\frac{76}{1,000,000}$ of a centimeter. Both types of waves, however, are manifestations in the same medium (the ether of space) and both travel through that medium at the same rate of speed, i.e., 186,000 mi. per sec. In the accompanying chart is shown the portion on the scale of ether vibrations occupied by radio waves.

Electromagnetic waves set up in the ether by a transmitting station are propagated in all directions at a velocity corresponding to that of light. As the distance from the transmitter increases, their amplitude or intensity decreases, due to the waves spreading out in ever widening circles and the consequent scattering of the energy content, and also because of the energy absorption by the different media through, or over which the waves may be propagated. Being of the same nature as

light waves, it might be expected that they are subject to the same laws as light waves, and, this, Hertz, in his early experiments, found to be true. He showed that the magnetic forces in the radiated wave varied inversely as the square of the distance from the small laboratory apparatus used to produce them. This, as no doubt, every engineer knows, is also the law which governs the distribution of visible light.

In ordinary radio practice where a grounded antenna is employed, the inverse square law may be applied with a fair degree of accuracy, at least up to distances of a few hundred miles. For greater distances, a number of variables affect its accuracy somewhat but in general it may be assumed to hold true. In considering the wave radiated from an ordinary broadcasting antenna, therefore, the energy available varies inversely as the square of the distance while the amplitude varies inversely as the distance.

With such tremendous attenuation or scattering of the energy in the radiated waves, it is obvious that the transfer of any reasonable quantity of power by this means, from one point to another, is economically impossible. Consider, for example, a transmitter where the energy available from the radiated wave at a distance of one foot from the transmitting aerial is one kilowatt per square foot. At a distance of 100 ft. from this aerial the energy available from the wave would be one-tenth of a watt. At a distance of one mile, it would be only

$$\frac{1}{27{,}878}$$

watt, and at a distance of one hundred miles, *one two hundred and seventy-eight millionth of a watt!*

Possibilities of Reflecting or Refracting Waves

In the foregoing discussion, reference was made to the fact that the electromagnetic waves used in radio work were similar in nature to ordinary light waves, and that they were subject to the same laws.

"Very well, then," someone will say, "if that is so, why not concentrate the whole output of a transmitting station into a narrow beam, by means of a suitable arrangement of parabolic reflectors and refracting lenses, in the same manner as in an ordinary searchlight?" This sounds simple enough, and since electromagnetic waves can be reflected and refracted, this may seem to be a reasonable suggestion, but a brief consideration of the practical difficulties to be overcome will show that this plan is equally impossible.

Exceedingly short electric waves, those of say less than a meter in length, have been reflected successfully by means of parabolic mirrors made of pitch or wax. Thus, Hertz used parabolic mirrors 12.5 cms. in focal length which were about 2 meters high for waves of about 66 cms., or about 2 ft. in length.

Such arrangements, however, are unavailable when long waves of 200 to 20,000 meters in length are to be reflected. It is absolutely impracticable to construct mirrors of dimensions comparable in size with the length of electric waves 500 or 1000 ft. long, and to employ smaller mirrors would be like attempting to conduct optical experiments with mirrors having dimensions of less than one hundred-thousandth part of an inch.

Even if it were possible, however, to construct suitable mirrors for the reflection of radio waves, the scattering tendency of such a beam would still render it useless for power transmission purposes. This scattering tendency is well seen in searchlight work.

According to Dr. Steinmetz, a beam of light starting with a cross section of one square yard at the searchlight mirror, will have scattered to an area of 2000 sq. ft. at a distance of 10 mi. from the mirror. At 100 mi. the cross section of the beam would be 16 sq. mi. To collect the wave energy in this beam at a distance of 100 mi. from the searchlight would require a collecting apparatus 4 mi. wide and, what is more difficult, 4 *mi. in*

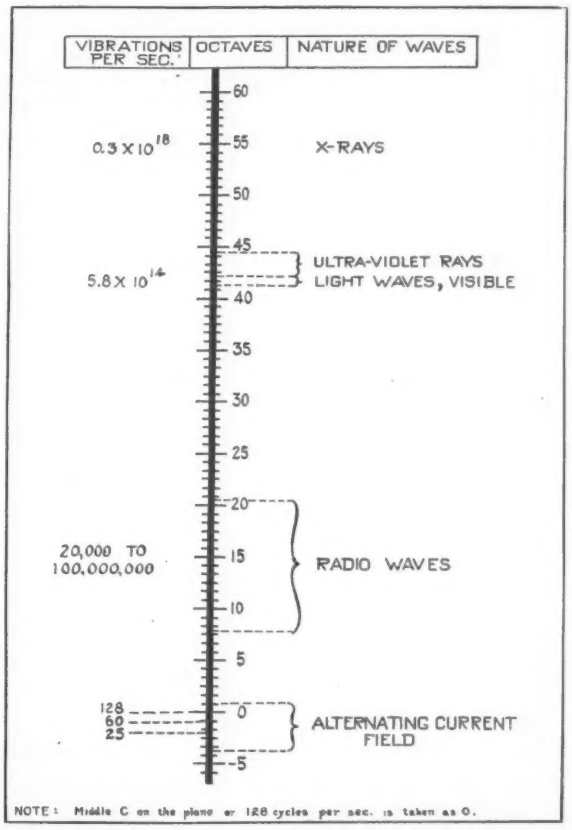


FIG. 1. CHART SHOWING SCALE OF ETHER VIBRATIONS AND PORTION OCCUPIED BY RADIO WAVES

height. It is evident, therefore, that even if reflecting equipment equal in accuracy to the best optical equipment were available for the reflection of electric waves, the scattering tendency of the beam would still prevent its being used for power transmission purposes except over very short distances.

Directional transmission by other means than by the use of reflectors, is, of course, possible. The excellent qualities of certain types of antennas are made use of in transatlantic radio communication, where stations on our North Atlantic coast are arranged to radiate most strongly in a north-easterly direction so as to increase the signal strength at the receiving stations in England and northern Europe. In Fig. 2 is shown a polar diagram showing the energy radiated by a bent antenna of the type shown at A. But even with this arrangement, the energy from our transatlantic transmitting stations is widely scattered over the entire European continent and the amount of power available at any

point in Europe is so exceedingly small as to appear meaningless when expressed in terms of watts.

Obviously, then, any plan for transmitting energy by radio, by any of the known methods, involves insurmountable obstacles. The losses due to absorption, and the inherent broadcasting tendency of the waves, make it an economic as well as a practical impossibility. The very fact that has made radio so useful in broadcasting intelligence renders it unfit for the purpose of transmitting power. Whether at some future time it will become feasible is a question which at the present time nobody can answer. The possibility is extremely remote.

Use of Standing Waves

In this connection, it may be of interest to consider briefly, the proposed use of standing waves, as discussed

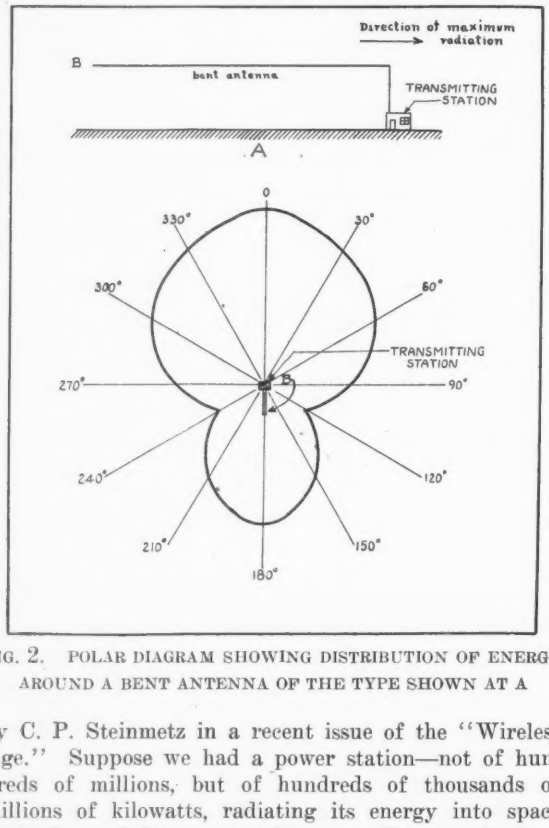


FIG. 2. POLAR DIAGRAM SHOWING DISTRIBUTION OF ENERGY AROUND A BENT ANTENNA OF THE TYPE SHOWN AT A

by C. P. Steinmetz in a recent issue of the "Wireless Age." Suppose we had a power station—not of hundreds of millions, but of hundreds of thousands of millions of kilowatts, radiating its energy into space in the form of electromagnetic waves. Suppose, furthermore, that this energy could be radiated into space at a wave length where the absorption was negligible.

Under these conditions, the waves would proceed in all directions from the station, and after passing completely around the earth would return to the generating station. If, now, the frequency was adjusted so that the returning wave was exactly in phase with the wave being radiated, no power would be lost. All the power sent out would return to the generating station, and the entire earth would be enveloped, as it were, in a sheet or shell of electromagnetic power. Only a little power would be required at the generating station to maintain this power sheet—merely enough to supply the slight losses, just as very little power is required to maintain the voltage wave in a wire transmission line when no current is flowing. It is a well known fact that no power is required to maintain the magnetic field around a current carrying conductor once it has been established. All the energy expended in building up such a magnetic field is stored up in the field itself and will be returned to the conductor when the flow of electricity ceases.

Suppose, now, that at a distant point from this "world" power station, we make use of the principle of resonance, and adjust a receiving antenna so that its natural period of electrical vibration is in exact accordance with the frequency of the radiated wave from the generating station. Energy will thus be absorbed, and power will flow into the receiving station, as though it were a hole in the power sheet. As soon as this occurred, the output of the power station would automatically increase until the amount radiated was equal to that absorbed by the receiving station. The amount of power radiated by the generating station would be equal, at all times, to the total power absorbed by the various receiving stations located throughout the world.

This is all very interesting and appeals strongly to the imagination; it is, however, nothing more than a dream. Whether it will ever be possible to build up such a sheet or shell of electromagnetic power around the earth is a question that, at present, must remain unanswered. Whether a wave length could be found at which the absorption would be negligible is also a purely hypothetical question. But truth has been shown to be stranger than fiction, and unless there were individuals in the world with imaginative minds, who dream about just such things as these, it is doubtful whether the many conveniences and essentials of modern civilizations that we have today would be in existence. A century ago, nobody, not even those gifted with the most flexible imaginations, would have dared to prophesy the fact that some day, a single person's voice would be able to make itself heard over half the earth's surface; yet, today, radio has accomplished this fact.

What the realization of radio power transmission would mean to civilization can hardly be imagined. Transportation would be revolutionized. Electric railroads would dispense with their overhead trolley wires or third rails and would take their power direct from space waves. Ocean vessels could throw out their ponderous engines and bulky boilers and no matter where on the seven seas they might wander, they would always have available an ample and unceasing supply of power. They would be given a new degree of freedom. The design and performance of aircraft would also undergo revolutionary changes. Eliminating their heavy power plants and making use of light electric propelling motors, their lifting power, their speed, and their range of travel would increase enormously.

In our cities and towns, power plants would vanish. The pall of smoke which now overhangs many of our metropolitan centers and industrial areas would be dispelled forevermore. The millions of dollars now spent for long transmission lines could be saved and applied to the betterment of humanity. It would be a changed world, but a better world to live in. Even "Power Plant Engineering" would have to seek new fields, but even this would not discourage us—we are willing to take a chance and if anyone can show us how to transmit power by radio, it will have our wholehearted support.

Engine Problems Solved by Use of Planimeter

PLANIMETER WHICH CAN BE MADE IN AN HOUR'S TIME OF VALUE IN SOLVING ENGINE PROBLEMS

UPON MANY occasions an engineer will find that it is an advantage to make some of the tools or instruments which he requires. This may be a question of efficiency or thrift both personal and in the interests of the concern for which he is working. The expenditure for an indicator may be as far as the superintendent will go at present and while that purchase is commendable the engineer will often require the use of a planimeter to help him out of some of his troubles.

Good use can be made of a planimeter when balancing the loads in the cylinders of a compound engine, when comparing the loads on several engines, or when studying the maximum, average or friction loads of engines; in fact, to have a planimeter is a satisfaction whenever it is necessary to figure the horsepower from indicator cards.

Fortunately there is a simple form known as the knife-edge planimeter, for which the tests to assure accuracy are simple and easily made. With reasonable care in making, testing and using this planimeter, results sufficiently accurate for all practical purposes may be obtained.

In Figs. 1 and 2 are shown two forms of the knife-edge planimeter. It consists essentially of a metal bar at one end of which is a tracing point and at the opposite end a sharp knife-edge. The tracing point must be sharp enough so that indicator card lines can be easily traced and still not so sharp as to dig into the paper. The knife edge must be sharp, true and in exact alinement with the tracing point. The alinement may be tested by placing the tracing point and knife edge on a straight line, then with the instrument held lightly at the tracing point end, move the instrument forward and backward along the line. If the knife edge departs from the line, it is not adjusted correctly and the fault must be corrected if accuracy is to be obtained.

Material required for the construction of the planimeter shown in Fig. 1 consists of two brass bars ½ in. by 1/16 in. by 12 in., five bolts ⅛ in. in diameter, a safety razor blade and a brass tracing pin. This construction has the advantage that the position of the blade may be easily adjusted to obtain the exact dimension of 10 in. from the center of the tracing point to the center of contact of the knife edge. This dimension is taken at 10 in. because results may then be read direct from a scale divided into 100ths of an inch; each division will represent 0.1 sq. in.

In Fig. 2 is shown another form of this instrument made from 3/16 or ¼ in. hexagonal steel, bent as shown, with one leg brought to a long tapering point and the other leg formed into a blade with a slight curvature. Proper alinement is of course essential.

When using this instrument, care must be taken not to tip it to one side or the other, for such tipping affects the accuracy of the results. It is also advisable not to use the instrument on paper so soft that the surface is scratched or scarred by the knife-edge, for this will also introduce an error. When the instrument is in good adjustment protect it carefully from injury.

Should it be desirable to construct an instrument of this type for areas larger than the ordinary indicator diagrams, it will be well to remember that the longest dimension of the figure whose area is sought should not be greater than one-half the distance between the tracing point and the knife edge.

To find the area of an indicator card, draw a line, AB, Fig. 3, tangent to the figure at any point. Select

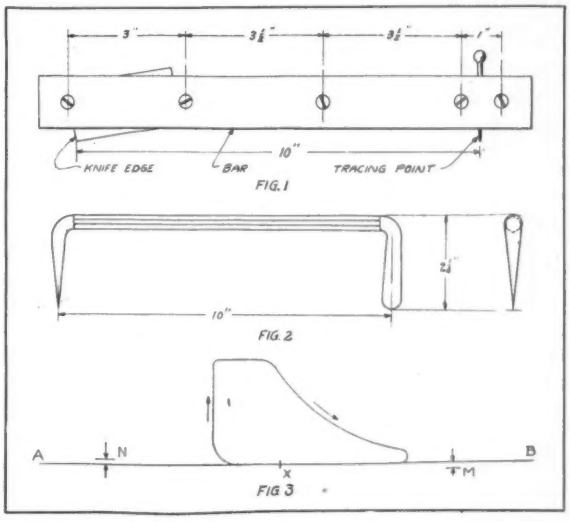


FIG. 1. PLANIMETER MADE OF BRASS STRIPS AND RAZOR BLADE

FIG. 2. PLANIMETER MADE OF ONE PIECE OF BAR STEEL

FIG. 3. TRACE THE DIAGRAM IN A CLOCKWISE DIRECTION

some point as X; place the tracing point on X with the knife edge on the line AB to the left; trace the figure in a clock-wise direction. The knife edge will now be found to be some distance, N, away from the line of tangency. A record of this distance, N, should be made. Then trace the figure again in a clock-wise direction, starting with the tracing point at X, with the knife edge on the line AB but to the right. When the tracing point has been returned to X it will be found that the knife edge is some distance, M, from the line AB; record this measurement. The area of the card will then be the mean of the measurements N and M multiplied by the planimeter arm length, or

$$\left(\frac{N+M}{2}\right) 10.$$

To illustrate by means of a problem, assume that the distance N, Fig. 3, represents two divisions on the 100 to the in. scale, or 0.20 sq. in. and that M equals 0.25 sq. in. As explained above, the area will be equal to

$$\left(\frac{N+M}{2}\right) 10 \text{ or } \left(\frac{0.20+0.25}{2}\right) 10 \text{ which equals}$$

2.25 sq. in. The mean effective pressure (m.e.p.) is equal to the card area, as found by the planimeter, divided by the length of the card, and this quotient then multiplied by the scale of the spring with which the diagram was taken. Assume a card length of 2.92 in. and a spring scale of 60, the mean effective pressure will be

$$\frac{2.25}{2.92} \times 60 \text{ or } 46.2 \text{ lb. per sq. in.}$$

In order to find the horsepower of an engine, we may assume for this problem that the card areas for the head and crank ends are equal, therefore with the same length of card the m.e.p. for the head and crank ends will be equal; this will be taken as 46.2 lb. per sq. in. as figured above. Assume an engine with a 20-in. diameter cylinder, 36 in. stroke, diameter of piston rod 5 in. and speed 100 r.p.m. The indicated horsepower of an engine is expressed by the following formula:

$$\text{hp.} = \frac{PLAN}{33{,}000}$$

in which P equals the m.e.p. for the cylinder or end of cylinder considered, L equals the length of stroke in feet, A is the area of the cylinder corrected for the rod area when necessary and N is the number of strokes per minute if the horsepower for both ends of the cylinder is to be figured or one-half the number of strokes if the power developed in each cylinder end is to be figured separately. The area of a 20 in. diameter cylinder is 314.2 sq. in. The area of a 5-in. rod is 19.6 sq. in. Then for the head end

$$\text{hp.} = \frac{46.2 \times 3 \times 314.2 \times 100}{33{,}000} = 132$$

and for the crank end

$$\text{hp.} = \frac{46.2 \times 3 \times (314.2 - 19.6) \times 100}{33{,}000} = 123.8$$

As is evident, the horsepower of the engine is the sum of these two quantities, or 132 plus 123.8 equals 255.8 hp.

This method will show whether the valves are set so that each end does about the same amount of work. This same method followed out for the two cylinders of a compound engine would show whether the two cylinders were doing about the same amount of work.

A Roadman's Adventure with a Maniac

SHELL SHOCKED EX-SOLDIER'S FANCIED GRUDGE GIVES ERECTING ENGINEER AN EXCITING TIME. BY GEO. H. WALLACE

WITH A thundering roar the Pioneer Express tore through the night, shattering the peace and quiet of the passing villages with the howl of its hoarse whistle as it sped toward its destination, miles away. The sleeper was well crowded and soon after stepping aboard, bound for a distant city where I was to erect a new engine, I found that my seatmate was a white haired man whose age was somewhat uncertain.

Erastus was busy making up the berths and diplomatically meeting all demands made upon him by sundry and divers persons who all wanted to be served at the same time.

My seatmate and I looked out into the night in silence, each busy with his own thoughts and wrapped in reverie. The lights of little towns flashed by, and the momentary roar as we passed a depot or a string of cars, came and went with seeming regularity. Now and again the cloud draped moon would be hidden by a flash of steam from the engine as we swayed around the curves, out along the river, in again through the rocky cut; and on and on, ever onward into the night we plunged, roaring, whistling, swinging.

"You ge'mens wish youah burffs made up now, sah?" and our night time day dreams were dashed to earth by the obliging porter inquiring as to our date of retirement. I looked across at my partner; he looked at me. Not a muscle moved on the face of either, yet we read each other like a book. With an instinct born of a similar nature we each reached into an upper vest pocket for a cigar, and at the same moment arose and started for the smoking room at the end of the coach.

I glanced at his cigar; it was the same brand as my own. He also was conscious of the fact, as I could see. "Here," thought I, "is a man much like myself; wonder who he is," and possibly he had similar thoughts.

"Nice night," I ventured as we settled into the cushions, though it might or might not have been, for all I knew.

"Yes," he replied as he glanced out into the passing kaleidoscopic streak while lighting his cigar. A quick inventory showed him to be a member of the American Legion, Spanish War Veterans, and certain fraternal orders. These coincided with my own affiliations. He also seemed to note my own emblems and watch fob.

"What branch of the service were you in during the great adventure?" I asked, indicating his Legion emblem.

"Heavy Artillery, 1st Div.," he answered, "and yours?"

"Heavy Artillery, 32nd Div.," I replied and we both smiled at the many points of similarity so far displayed.

"What is your line?" he asked, reaching for his card case, and an exchange showed that with so many characteristics in common, that we were to have still more, for we were both erecting engineers for different concerns and on our way to new jobs in the same territory.

"Fritzie must have come pretty close to you," I ventured, as a guess, "your hair is pretty white."

"No," he replied, with a glance at my own black hair, "it was like yours until about 2 yr. ago when it turned white within a few days," and a shudder passed over him. After a pause, he seemed to overcome his fright a little and said, "And since you and I seem to have so many things in common, possibly you might like to hear about it?" Of course, I was eager to accept his offer.

"Well," he began, "I had been over at Blankburg installing a large cross compound engine and was having the usual general run of luck. Some of the help was

fairly intelligent, and some didn't even suspect anything. There was a young lad on the gang, an ex-soldier, 'even as you and I,' who, I was told, was shell shocked over across, and was taking a course of training.

"It took me but a few days to arrive at the conclusion that this young man was not put together right and that he was not mentally responsible. He had a shock of dark hair which he habitually combed low over his forehead, which with his evil eye gave him a sinister appearance. When he thought that I was not watching him or if I looked up suddenly he would be leering at me, as if he had me picked for the firing squad or something like that.

"I inquired a little about him from the Chief, who said that the man had been hit by a shell in the war and had a bad dent put in his head over the eyes. This explained the long hair. Still with all the fellow's peculiarities, we got on fine. He said little, but was very willing, even anxious to learn.

"There is something that draws ex-soldiers together, as we have been tonight, and I took quite an interest in this fellow and showed him many things that the average operator is not in a position to learn from the roadman. He had studied diligently on power plant subjects and was fairly well grounded in the principles of engineering. When it came to setting the valves and eccentrics, he was a great help to me.

"After the usual heart breaks that all erectors know, we started up, and soon had the engine on the load in parallel with the other units in the old plant to break her in. Naturally the first run, as you know, develops all the looseness in the pins and bearings, so we shut down and proceeded to take up while the engine was still at a running heat. I had gone over everything but the high pressure crankpin and crawled into the enclosed crank case there with the necessary tools, and soon had the job done.

"It never occurred to me that anything might happen. I knew that the throttle was tight; but as a matter of precaution, I had unhooked the hook rods and placed the wristplates in the central position, both sides and believed everything safe.

"While I was fussing with the take-up wedge, I half imagined that I heard a suspicious noise which struck me as if someone was hooking in the low pressure hook rods, but gave the matter little thought.

"But following right on the heels of that noise was a similar one, and now I knew that someone was hooking in the high pressure rods. Still I did not suspect any trouble. I was just gathering up my tools, and, in fact, had thrown all of them out through the manhole in the guard, except a short bar, when I heard the fiendish yell of a man unmistakably stark mad.

" 'Oh, I've got you now,—I've got you now. Maybe you don't know *me* but I know *you*. You are that damned Prussian that cut the top of my head off at Montfaucon with an ax, and now I'm going to kill you. I've got you,—I've got you,—and you are going straight to hell where you belong,' and his maniacal, hysterical laugh was partially drowned by the hiss of steam, and then I began to realize what it was all about.

"I had decided that I could wiggle out of the hole in the crank guard quickly and was about to try it when I saw the crank move, and it then required all of my energies to keep out of its way. I was standing near the hole, with one foot on the head of a capscrew and the other on the 3-in. ledge of the oil pan, and my right arm through the manhole.

"Slowly the crank swung towards me, and though it was a large engine, yet when you see a fiendish juggernaut coming at you in a confined space, it looks twice as large. With a spasmodic wiggle, I managed to maintain my position while the crankpin brushed my clothes in passing. This seemed to be death reaching out for me, for I realized that this demented fiend would soon bring the engine up to speed, and sooner or later,—maybe sooner,—I knew that I would slip and fall under the end of that connecting rod and if not killed outright, would be disabled in such a manner as to make the passing of my earthly affairs a painful matter of seconds.

"To get out was impossible. I realized that. Even had the manhole been large enough, the interval between revolutions was too brief. The important question now was to hold myself in a secure position until someone would come in and find this crazy man running at large, and shut him up, and the engine down. But would I last that long?

"Then I wondered what had become of the Chief, whether the lunatic had killed him and the rest and was now in undisputed possession of the plant and free to carry on his fiendish work without interference. Where were the electricians? Where were the watch engineers? Where were the hangers-on that are always under foot on a job of this kind? Could he have killed the whole outfit without raising a disturbance? Was I the last man alive?

"These and many more were the questions that flashed through my brain, and it was not until weeks later that I learned that two innocent tin chariots had taken a notion to occupy the same place at the same time on the public highway right in front of the plant, and the commotion had for the moment attracted all hands to the scene, except the crazy man and myself. The Chief said that he had been away not any longer than 3 min.

"But here came that ponderous crank again. This was the main issue now; how to dodge it this time, and how to continue to dodge it indefinitely for it now seemed to me that I surely was in a devil of a predicament. Several times more it came and caressed me and passed on. I came to look for it as one does for the arrival of a friend; it never disappointed. It was always on time right to the dot.

"Then another thought came to me suddenly,—did the darn fool turn on the oil? Even in my own extremity, the safety of the new engine was uppermost in my mind. Five minutes, 10 min., or even more, I knew would not matter much, for the engine had been shut down but an hour or so and the bearings were surely well coated with oil yet. But did he turn on the oil or was he going to ruin the new engine as well as kill me?

"A drop of something hit me in the eye; it was oil. That drop was nearly the death of me, as the momentary shock of it caused me to forget myself for the moment, and my right foot slipped off the head of the capscrew which in turn caused the other to slip off the narrow ledge in the oil pan. I was turned completely around with my back to the pin and my feet dangling in the

crank pit while my whole weight was supported by my right arm thrust through the manhole.

"I clung to the small opening for dear life while the end of the crankpin came around and grabbed me by the waistband of my overalls behind. Fortunately they were old and how thankful I was when they gave way under the strain. The cloth was dragged through the oil in the bottom of the pit and then derisively flung in my face by the crankpin as it swept by majestically. After three or four such taunts, the oily rag dropped off and fell into the recess of the oil pan just in front of the slide. This gave me an idea. Why not get back there myself where it would be safe? But how?

"Already the maniac outside had increased the speed a little, and, though I was in no mood to take the speed with a stop watch, I judged it to be about 45 to 50 to the minute, and I was sensible of a gradual increase each moment. What was to be done must be done instantly. I knew that within the next few seconds I would be either safe so far as immediate death was concerned, or else a crushed mass of pulp like we used to see sometimes 'over there.'

"There was room for me to slide towards the back end of my oily prison while the crankpin was passing over the top half of its circle; but there was an element of chance even in attempting this feat, for if I slipped on the semi-circular bottom of the oil pan and missed my calculations, that crank would come around and catch me before I could recover myself.

"Still, that blood curdling yell again, and a substantial increase in speed demanded decision instantly, and, —I chose to try it. I watched one more flight of the crank as it passed, spitting oil at me in glee, to time its movement accurately, then as it swept downward on its backward stroke, I gripped firmly the little bar that I still had with me (though for the life of me I didn't know what I was going to do with it) and dived after the retreating end of the connecting rod, and in under the center crank oiler.

"Just as I suspected I might, my foot slipped on the oil and I lost my headway. I looked up and saw that 2-T. rod bearing down on me, and realized that this was about the end. Still, I defied it and even smiled a little, I think, and dared it to catch me. It seemed like some new kind of a game, and I figured that I was a little more expert at it than the crank was.

"Somehow or other it seemed that I was back 'over there' again and that this was one of those infernal 210's trying to find where I was, or a droning Fokker Bomber seeking me out beneath a clever camouflage. One or the other got me. With a rush and a splash it swept on with increased speed and before I could get myself into a position to dodge, the end of the rod, or the shell, or the bomb,—I was not sure which,—struck my left leg below the knee. I waited an age it seemed for the explosion, but it did not come.

"Still I did not give up. With a supreme effort I wrenched myself free as the cause of my trouble swept on and up. I huddled into a place of safety in the corner of the crank case with my useless leg dangling in the path of the greasy crank, but just out of danger.

"I was fully conscious of the regular increase in the speed for I could feel the jar of the dashpots suddenly die away as the engine came under the control of the governor. I was safe for the time being, but unable to move a muscle as that ponderous connecting rod swept past my face and up again, smearing me anew with oil each time.

"The fiend came to the little opening in the guard and shrieked his curse on me again, 'I've got you now, you damned Hun, where you won't cut the top of my head off any more. You're going to die and go to hell with the rest of my buddies that you cut the heads off that day. Oh, but I've got you now where I want you, and you can't get out. I knew you, I knew you. I am going to kill you deader than hell,—that's what I am,' and with that he threw a piece of scantling into the crank case.

"The fantail of the crank caught it and splintered it, throwing the pieces all over me and back into the slide where the crosshead gave them a few more raps. Then I heard the door of the engine room slam and he rushed out yelling as he went.

"I learned later that as he rushed through the door he headed for the river near by, saying, 'I've got him, I've got him,' and the Chief and the rest of them who were just then returning stopped to watch him in wonder, naturally not knowing what was the matter and though hearing the engine running inside, supposed that I had finished my adjusting and started up.

"They followed him to the water in a hurry, thinking that by his remarks that he was going to rescue someone from a watery grave. When he reached the brink, he paused long enough to turn and yell, 'I've killed him. I knew him, but he didn't know me. He cut the top of my head off at Montfaucon, but I knew him and I killed him,' and before anyone could stop him, he threw himself into the raging stream where he soon was drowned.

"While the others tried to rescue the maniac or at least recover his body, the Chief and the Electrician returned to the engine room. I heard the door slam behind them and heard their confused voices; but though they came and went and looked all around, nobody seemed to realize the true state of affairs. They went out to the boiler room, but naturally the firemen knew nothing about the matter.

"Realizing that so far as they were concerned, I was completely lost, I thought of trying to attract attention. My field of action was very limited, as that connecting rod was continually passing and repassing within a few inches of my face. Getting the rhythm of the movement of the rod, I was able to strike a blow on the crank guard at each revolution with my short bar, and soon the Chief stuck his face into the opening and yelled out, 'Hello in there; anyone in there?' little believing that there really was.

"'Yes, I am. Shut her down; she is running light,' and soon I heard the thump, thump, thump, of the heavy dashpots as the engine began to slow down, and soon stopped. As the connecting rod swept by me for the last time and came to a stop on the top quarter, everything seemed to grow dark. The last I remember was sliding down into the slippery bottom of that oil pan on my back with my left foot pointing to the heel of my right, and as I cast my eyes towards the opening I saw a huge face coming in. It was the Chief. Then the sun went down.

"Three weeks later, which to me seemed about 3 sec., I came out of it in Columbia Hospital and by the side of the bed was a nice little nurse who seemed familiar to me and a second look revealed my daughter, who had been called from her own hospital to pull me through if possible. Beside her sat a young man, hair combed back and wearing bone-headed glasses, feeling of my pulse. As I looked up at him he said, "Well, how are you feeling, Dad?'

"Yes, he was my son who had come from a New York hospital where he had been stationed, just as soon as he heard of my accident, and those two kids of mine had a great deal to do with my recovery. Dr. Ivan told me not to talk too much and it seemed but a few years ago that I was telling him that he had too much to say.

"Next day they let me look at myself in a glass and my hair was as white as you see it now. The Chief was admitted a few minutes and told me that the engine was accepted and was carrying full load right along. Also that the army student had evidently gone clear off the handle. He had told some of the boys when I arrived that he knew me and that I was German, because he had met me in France, and that some day he was going to fix me for something that I did to him once. And he came pretty near getting me, too."

"You ge'men's burffs am done made up, sah."

When Replacements Effect Savings

Methods Used to Calculate Economy Which May Be Expected by Replacement of Steam Generating Equipment

IN GENERAL, the replacement of power generating equipment is made in order to effect an economy in power production or to bring about greater reliability in service.

Before seriously considering the purchase of new equipment it must be made certain that the existing equipment is operating at its highest possible efficiency. With that condition established, the problem of replacement may be reviewed from one or more of three phases; namely, obsolescence, inadequacy or natural depreciation.

Obsolescence cannot be predicted, it is dependent upon invention. It demands that a unit which has been doing its work as economically as was originally contemplated, which has required only slight repair charges and which has many more years of useful life remaining, be sold at scrap value and replaced by some other type of equipment which will do the work more economically and satisfactorily. Replacement of hand firing by mechanical stokers, steam engine units by turbines, small turbines by large turbines, are examples of obsolescence.

Adequacy is dependent entirely upon the faculty of the present equipment to meet the demands that are placed upon it. This may involve the adequacy of types of units or the adequacy of present facilities as applied to the entire plant. The designing engineer is generally justified in providing machinery adequate only for the natural expected growth of an industry, therefore a time will be reached when more modern and efficient equipment will be required.

Equipment may depreciate physically due to long years of service, each year will bring about added expense for maintenance. This condition will finally reach the stage where it would be an economy to sell it at salvage value and replace it with new equipment even if of the same grade and kind.

There are numerous instances where in spite of large expenditures for maintenance it is better to keep the old equipment running than to purchase new because the savings due to increased operating efficiency do not equal the loss brought about by the expense of removal of the old equipment and the annual charges on the more expensive new equipment. This condition will no doubt exist in many hand-fired boiler plants, where are operated boilers of a capacity which we would term small in present day practice. The problem may resolve itself into an economic comparison between natural draft stoker installations in small unit capacities as compared to forced draft stoker equipped installations of large unit capacities.

Generally, during the term of operation of old equipment, progress will have been made in the design and economy of the equipment under consideration so that replacement due to physical depreciation may actually result in economies of operation as well as of maintenance. In many industrial boiler plants, an economy due to a change could not be shown until natural depreciation had set in to the point where the boiler insurance company would soon recommend a reduction in boiler pressure. Should the problem reach this stage, it is often of interest, in fact, it may be demanded of an engineer, to prepare a statement as to the anticipated savings due to the new installation.

When an occasion of this kind arises, it is to be expected that the new equipment will be somewhat more economical of operation than is the old. As a problem, we may assume a natural draft chain grate stoker installation consisting of twelve 250-hp. units which is to be replaced by five 800-hp. units equipped with forced blast chain grate stokers. Assume that the old plant, having operated for 18 yr., has reached the point where it would appear that it is less efficient than the contemplated new units would be. A formula developed by H. P. Gillette, and applicable to this problem, is as follows:

$$\frac{Cr + D\,(C\text{-}S) + M}{Y} = \frac{rs + m}{y}$$

In this formula capital letters refer to the new plant and small letters to the old plant. If the part of the equation on the right of the equality sign is equal to or less than the result obtained by solving the left-hand side, no saving can be made due to a change in equipment.

C equals first cost of the new plant.

r equals interest rate including risk insurance, taxes and proprietary supervision or management. It does not include the equated annual operating expense for either the new or old plant, nor does it include the functional depreciation annuity rate for either the new or old plant.

D equals depreciation annuity for total natural life.

S equals salvage value of the new plant.
M equals annual operating expenses other than depreciation of the new plant.
m equals annual operating expenses other than depreciation of the old plant.
s equals salvage value of the old plant.
Y equals the annual output in units, new plant.
y equals the annual output in units, old plant.

The factor D may be obtained from the formula:

$$D = \frac{r}{(1+r)^N - 1}$$

in which r is as previously stated and N equals the estimated life of the plant in years.

For both the old and new plant, we may assume the salvage value (S and s) of the equipment will not exceed $3000. We may assume further that:

B.t.u. of coal as fired	10,100
Cost of coal at stokers, per ton	$4.00
Interest rate, per cent	4

Operating expenses for the old plant may be figured as follows:

Average number of boilers in operation	10
Number of hours operated per day	24
Days operated per year	300
Average rating developed, per cent	160
Estimated total thousands of boiler hp. developed per year (y), 10 × 250 × 1.6 × 24 × 300 ÷ 1000	28,800
Average evaporation per lb. of coal (from records)	6.05
Lb. of coal per boiler hp.-hr., 34.5 ÷ 6.05	5.70
Cost of coal for one year, 28,800 × 1000 × 5.70 × 4.00 ÷ 2000	$328,320.00
Maintenance material and labor, attendance and misc. (from records), dollars per 1000 boiler hp.-hr.	0.77
The above item for one year, 0.77 × 28,800	$ 22,176.00
Total operating expense (m)	350,496.00

For the new plant we will have the following:

Estimated first cost (C)	$490,000.00
Average number of boilers in operation	4
Number of hours operated per day	24
Number of days operated per year	300
Average rating developed, per cent	160
Estimated eff. of boiler and furnace, per cent	70
Estimated thousands of boiler hp.-hr. developed per year (Y), 4 × 800 × 1.6 × 24 × 300 ÷ 1000	38,864
Evaporation per lb. of coal, lb., 0.70 × 10,100 ÷ 970.4	7.28
Lb. coal per boiler hp.-hr., 34.5 ÷ 7.28	4.74
Cost of coal for one year, 36,864 × 1000 × 4.74 × 4.00 ÷ 2000	$349,470.00
Estimate of attendance, maintenance and miscellaneous	15,000.00
Total operating expense for the year	364,470.00

The depreciation annuity D based on a 20-yr. life of the new plant, will equal:

$$\frac{0.05}{(1+0.05)^{20} - 1} = 0.0303$$

Substituting now in the original equation we have for the left-hand side (new plant), 490,000 × 0.05 + 0.0303 (490,000 — 3000) + 364,470 ÷ 36,864 = $10.95 per 1000 boiler hp.-hr., and for the right-hand side (present plant) we have, 0.05 × 3000 + 350,496 ÷ 28,800 = $12.20 per 1000 boiler hp.-hr.

Since $10.95 is less than $12.20, it is apparent that the cost per 1000 boiler hp.-hr. as produced by the new installation will be less than the corresponding cost of maintaining the old plant in operation and it will be profitable to make the change. The saving, in this case, will amount to approximately 11.4 per cent, based on a cost of $10.95 per 1000 boiler hp. and the estimated thousands of boiler horsepower which it is anticipated the new plant will produce.

Production of Petroleum Products

PRODUCTION OF gasoline in the United States in January amounted to 623,823,337 gal., and established a new high monthly record. The figures show an increase of approximately 39,000,000 gal. or 6.6 per cent over the previous record month's output, that for December, 1922. Reports from 301 refineries operating during the month indicated that on Feb. 1 the nation's stock of gasoline amounted to 1,002,857,273 gal., the largest supply ever recorded. Stocks of gasoline were increased during January by 119,000,000 gal. Gasoline stocks on Feb. 1 were nearly 300,000,000 gal. in excess of stocks on the corresponding date in 1922. The indicated domestic consumption of gasoline in January was 443,128,456 gal., excluding imports for which figures are not yet available.

Domestic production of kerosene in January amounted to 212,447,902 gal. Consumption of kerosene was 123,214,097 gal.; exports were 94,847,333 gal. Stocks on hand Feb. 1 were 275,436,804 gal., a decrease of more than 5,000,000 gal. during the month.

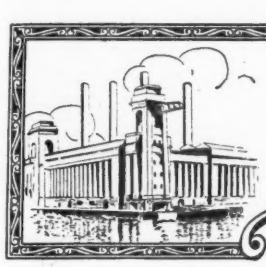
Production of gas and fuel oils in January is given as 989,376,102 gal. Consumption of these oils amounted to 931,829,391 gal. Exports were 97,199,839 gal. Stocks on hand Feb. 1 were 1,265,074,722 gal., a decrease for the month of 39,000,000 gal.

Output of lubricants in January amounted to 87,077,868 gal. Consumption of lubricating oils is reported at 49,061,520. Exports were 33,061,486 gal. Stocks on Feb. 1 amounted to 240,689,649 gal., a decrease of 5,000,000 gal. during the month.

Classification of Waste Fuels

WASTE FUELS are grouped by the Bureau of Mines into two distinct classes—"Autocombustibles," which maintain their own combustion after ignition, and combustibles which will not burn without the addition of heat from an outside source or without mixture with an autocombustible. This second class may be termed for convenience "semicombustibles." With the improvement of furnaces for handling waste fuels, certain materials that were previously considered as semicombustible have joined the list of autocombustible fuels.

Semicombustible fuels resist self-ignition mainly because they contain excessive moisture, ash and refuse, and have a physical structure that tends either to resist the passage of the draft or to form large openings in the fuel bed that admit much more air than is required for combustion; too little or too much air lowers the furnace temperature and the conditions that make for efficiency.



LETTERS DIRECT FROM THE PLANT

Unusual Method of Scraping a Babbited Bearing

SOME YEARS ago, I was engaged as assistant construction engineer erecting a large pulp drier plant. The plant consisted of several presses, scrolls, the driers, and fans. The line shaft was divided in the center by a short jack shaft, belted to a Corliss engine by a 48-in., 3-ply leather belt. Each end of this jack shaft was provided with a clutch, so that either half of the line shaft could be started or stopped at will. The line shaft bearings were of the rigid pillow block style, bolted down onto the steel channels, and shimmed up, until the shaft was level throughout. The bearings were of the ring oiling type, the ring being of the spring joint variety, the points locking together by spring of rings.

I pointed out to my chief the unreliability of this type of ring, but time would not permit our substituting them with a better type.

When the plant was started up, the bearings gave little trouble, which was fortunate because our time was fully taken up with other parts of the plant, principally the fire driers which required careful handling, and the gaining of experience on my part.

We had been at it from early until late for several days, and things were beginning to ease up a little, when one day the oiler came hurrying to me with the news that one of the bearings was smoking hot. I ran to the clutch connected to the shaft of the smoking bearing and stopped the shaft. The hot bearing was the one next to the clutch, the shaft there being 8 in. in diameter, and the bearing had a length of about 20 in. I removed the bearing cap and found that the babbit had begun to melt, some of it having been brought up to the joint of the bearing. I also discovered that the heating of the bearing was due to one of the rings being hung up by a slight projection at its joint.

Before serious damage had been done to the bearing the shaft was stopped, and all that seemed necessary was to give the bearing a good scraping to make it serviceable again. This was easier said than done, because the bearings were all of the rigid type, and to get at it would mean raising the shaft or lowering the bearing away from the shaft. The former, due to the peculiar design, entailed the removal of the 48-in. wide 3-ply leather belt, the dismantling of both clutches, and the raising of the jack shaft before the shaft of the damaged bearing could be disconnected and raised. The latter entailed the removal of the steel supporting the bearings.

Either of these plans would take considerable time to carry out, so it was decided to try the effect of sulphur, sapolia, white lead, or graphite to make the bearing run cool. All of these were in turn tried, and all failed. As soon as the shaft was brought up to its proper speed, i.e., 260 r.p.m., then the bearing would become dangerously hot again. The trouble started about noon, and from that time until evening, the struggle continued without good result.

During this time, I remembered the outboard bearing of a Corliss engine I had erected some years before and how one end of that bearing persisted in running more than warm. As I had pondered over that bearing, I had wondered why one end should run warmer

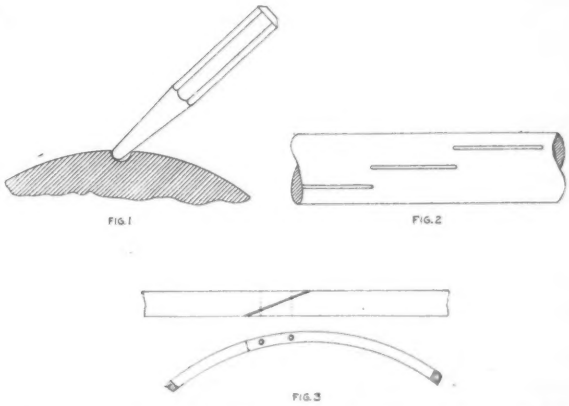


FIG. 1. GROOVES WERE CUT IN THE JOURNAL PARALLEL TO THE AXIS WITH A ROUND NOSE TOOL

FIG. 2. FOUR CUTS WERE MADE WITH FOUR OVERLAPPING SCRAPING EDGES

FIG. 3. OILING RINGS WERE SPLIT AND THEN RIVETED TOGETHER IN PLACE

than the other. I reasoned that the pressure was not evenly distributed and that the cure was to remove the high places, and to do this without raising the shaft or removing the bearing. All that was needed would be a slight burr such as would be produced by nicking the surface of the journal parallel to its axis with a sharp flat chisel.

It was a passing idea not adopted then but now it returned again and I welcomed it as a possible solution. I was satisfied that the faint chisel cut would scrape the bearing, but what about the scrapings. I decided that the chisel cut must have a groove for the scrapings to rest in. I imparted my idea to my chief and he in turn to the representatives of the owners of the plant. We went into conference and I was asked if I had ever tried or seen such a scheme tried before. I had to admit that I had not, but I was able to convince them that it would prove satisfactory. As it was the quickest way to get the plant going again, I was told to go ahead.

I first made a round nose which I carefully ground to cut a groove about 5/16 in. wide. Then with a box square I marked two parallel lines on the shaft journal

and parallel to its axis about 5/16 in. apart and 6 in. long. Commencing at the end of journal over the damaged part of bearing, I carefully cut a groove between these lines, dipping the point of the round nose in a pad of oily waste to insure a clean, smooth cut. The groove cut, I smoothed its edges with a fine cut file rounding off one edge. I then made a tool like a fuller, and carefully raised the other edge from end to end (Fig. 1). This done, I took a flat, smooth cut file and oil stone and reduced this edge so that with a straightedge laid on it, it showed but a few thousandths above the rest of the shaft.

Now came the time to try it out. A couple of men slowly barring the engine, the shaft began to turn, and the grooved part entered the bearing. I hardly breathed until it reappeared again, which it soon did, laden with black burnt babbit, and a little bright babbit. Another little rub with the oil stone, and again it was given a turn. On its next appearance, it contained less burned babbit and more bright babbit. It was sent a few more journeys and we considered that part well scraped.

The cutting edge of the groove was then removed and this edge of the groove rounded as had been the other, and another 6-in. groove cut in advance of and slightly overlapping the first. This was prepared and made to scrape its portion of the bearing.

In this manner, with four such grooves, the entire length of the bearing was scraped; Fig. 2.

In the meantime a pair of oiling rings had been made to replace the originals. The new rings were made out of a piece of pipe of suitable size, bored and turned, and rings of required width parted off. These rings had to be split, and then assembled on bearing. Before splitting them, two holes were drilled through the edge of the ring where the split would come, and the holes slightly countersunk. The ring was then split diagonally on both sides, as shown, with a thin saw. After splitting, the rings were assembled on the journal with a liner the same thickness as the saw blades in the joint. This made the ring the same width at the joint as elsewhere. Soft brass rivets were used to secure the halves of the rings together and the result was an oiling ring a perfect circle and free from projections, as shown in Fig. 3. I filled the oil well with a mixture of cylinder oil and ordinary bearing oil, and started up, and that bearing right from the start ran cooler than ever before, because those grooves helped to keep a good film of oil between the journal and the bearings.

Grooving a bearing was new to me then; but since, I have come across several instances of it. Once I saw a large Corliss engine of German make being erected in Peru, on which the crosshead pin, crankpin, and journals were all grooved.

I once caused considerable consternation among the officials of a plant, where I was sent to overhaul a Corliss engine, when they found out that I had cut a flat on the journal of the engine. I had been informed by the engine attendant that that bearing had always run too warm and after examining it, and the belt drive, I decided that a flat would help to carry the oil to where it was needed. I so drastically treated the journal that, until that engine was put to work again, and until the bearing proved cooler than before, my sanity was in question.

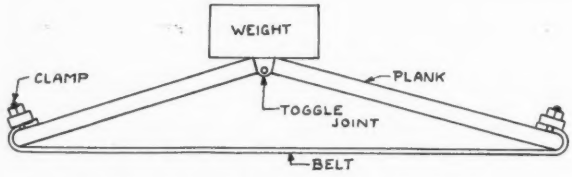
Sugar City, Idaho. E. J. JORDAN.

Stretching Belts*

SOMETIMES BELT users are advised to stretch all belts before using. This is not good practice because the best belt manufacturers today carefully stretch the leather before sending it out, and it is certain that a belt manufacturer equipped with stretchers can do better work than can the belt user not properly equipped.

In my belting experience, I have seen such horrible examples of stretching devices as shown in the accompanying sketch. The device consists of two planks arranged in toggle joint fashion. These are hinged in such a way that when straightened out an enormous force is created and the belt stretches.

This is not good engineering, because the stretch may be made so great as to injure the strength of the belt to such an extent that it will fail prematurely. There is usually no good reason why initial stretch should be taken out of a belt, anyway. If the belt is properly



A HORRIBLE EXAMPLE OF BELT STRETCHER

cared for in the first place and so treated that it will not slip, the stretch will take care of itself by increasing the slackness and thereby increasing the arc of contact on both pulleys.

Numerous belt drives are in existence that are running slack and have not been cut for 18 yr. or more. When they are cut it is only because they become so slack that the sides begin to touch, and that, of course, is bad. In fact, a belt should always be so slack that the sides nearly touch—especially horizontal belts. Vertical belts, of course, cannot as a rule be run slack, but there is no reason why they should be operated with drumstring tightness.

Newark, N. J. W. F. SCHAPHORST.

Why the Trap Could Not Furnish Sufficient Water

FREQUENTLY WE have trouble with a piece of apparatus in our plant and in looking for the cause it is not infrequently that we find it in an altogether different location from where we were looking for it.

In a steam plant where a tilting trap is used for boiler feeding, it was noticed one day that the trap failed to furnish sufficient water to the boiler with the water supply valve wide open and the trap apparently in good working order. This was a puzzle for some time. The trap and connections were examined a number of times, but nothing found that possibly could cause the trouble. In looking for the cause, it was noticed by one of the employes that there was more steam escaping at the blowoff tank vent pipe than usually was the case. (The outlet of the vent pipe is located outdoors.) The attention of the engineer was called to this matter; he, of course, knew at once where

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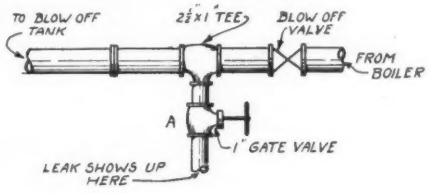
the trouble lay, as the blowoff valve was leaking badly. It is the practice in this plant to blow some of the dirty water out of the boiler, mornings and noons. This time the valve was not closed tightly because of a piece of scale or other foreign matter that was lodged between the seat and disc. By opening and closing the valve a few times the leak was stopped.

Shortly after the blowoff valve stopped leaking, it was noticed that the water in the boiler gage glass was rising, hence it was found that there had been nothing wrong with the trap in the first place, but that more water was leaking out of the blowoff valve than the trap was able to make up for.

This trouble would not have occurred had the engineer equipped the blowoff pipe with an arrangement on the discharge side of the blowoff valve as shown in



SCHEME FOR DETECTING A LEAKY BLOWOFF VALVE

the accompanying illustration. With this arrangement, it will be noticed at once whether or not the blowoff valve is leaking by leaving the valve "A" open when the blowoff valve is closed. Any little leakage past the blowoff valve will show up here at once.

In another instance a tilting trap used for boiler feeding started to fail in furnishing sufficient water to the boiler with the water supply valve wide open. In looking for the trouble, it was found that the lock nut holding the valve stem on the steam valve in place had worked loose. This allowed the valve stem to screw into the stem holder, which in turn made the stem too short, hence the steam valve could not close tightly when the trap tank was in the filling position, as steam would leak into the tank, causing a back pressure so that the water could not run into the tank. After the stem and valve were adjusted, there was no further trouble.

Milwaukee, Wis. H. A. JAHNKE.

Adjustable Scaffold Without Nails

ON PAGE 389 of the April 1 issue of Power Plant Engineering, there is an illustrated article on the construction of scaffolding by G. A. Luers, which reminds me of a simple scheme I saw worked out successfully and used for the same purpose.

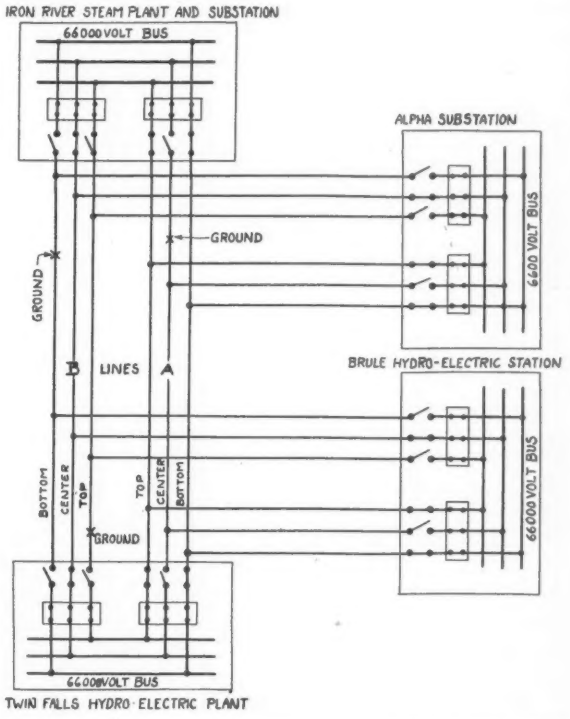
Eight strips of wood 7 in. wide by 1⅛ in. thick and of several different lengths, had notches several inches deep, and wide enough to pass over ladder rungs, cut into each end of each strip. These strips of wood were hooked onto the rungs of a pair of ladders, some diagonally, some straight. Not a bolt or nail was used. Planks were then placed upon the rungs of each ladder at the height desired by the workman, as a platform. The heavier the load upon the plank the more tightly the ladders will be held. It is impossible for the strips to slip off the rungs; they must be lifted off.

Toronto, Canada. JAMES E. NOBLE.

Storm Necessitates Emergency Operating Condition

WHEN A severe lightning storm visited the upper peninsula of Michigan it caused some insulator failures on the Peninsular Power Co.'s 66,000-v. lines; at the Twin Falls hydroelectric station where the line testing is done, we finally had to give up trying to keep the lines alive as Line A had one wire grounded while Line B had two wires which, of course, caused a short circuit.

As we have an ammeter for each line wire, we were able to know that our center wire was grounded on line



SHOWING EMERGENCY OPERATION OF 66,000-V. LINES WITH 3 GROUNDED WIRES

A while the bottom and top were grounded on line B. We therefore pulled the disconnects on each of these wires and notified the other stations to do likewise.

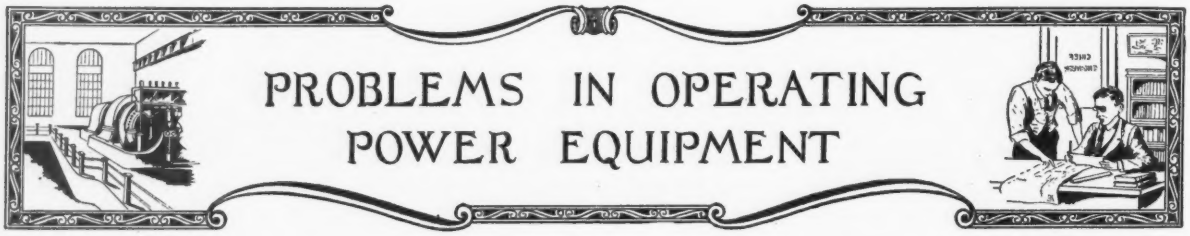
This method of operation proved successful until the line trouble was repaired.

Iron Mountain, Mich. L. W. WYSS.

Paint for Cement Floors

THERE ARISES, many times, the question of what is the best paint to apply to new or old concrete floors—something that will be durable, and impervious to temperature changes, water, oil or acid. A paint that will meet these conditions may be made of one part kerosene and one part cement.

Thoroughly mix by sifting the cement into the kerosene slowly and stirring vigorously. After thorough mixing has been secured, mix with four parts of real coal tar—not oil tar. The resulting paint is a good, substantial, heavy body paint that is impervious to temperature changes, water, oil and acid, and one that has good wearing qualities. C. C. BROWN.



Coal for a Year's Run

CAN YOU give me an approximation of the amount of coal necessary for a year's run to perform the following combination:

To operate a 10-T. ice plant—

3 months in the year.....24 hr. a day
3 months in the year.....12 hr. a day
6 months in the year.....idle

The same boiler supplies steam for electric service all the year, 24 hr. a day, with loads as follows:

12 hr. of the day with load averaging.....20 kw.
3 hr. of the peak load averaging.....50 kw.
9 hr. of the night load averaging..... 5 kw.

A. P. W.

What Refrigerating Capacity Will Be Required?

GIVEN A cold storage room 81 ft. long by 67 ft. wide by 13 ft. high with 13-in. brick walls insulated with 4-in. cork board; ceiling insulated with 2-in. cork board; all cork plastered with ½-in. cement, temperature in room to be kept at 40 deg. F. Goods stored: Evaporated milk in one-pound tin containers packed in fiber boxes. Daily input into room, 50,000 lb. of milk at 80 deg. F. Specific heat of goods, 0.93. Three men working in room 8 hr. a day. Cooling medium, 2 in. direct expansion coils on ceiling. Compressor to do the work in 12 hr. daily. Cooling water available for ammonia condenser, 80 deg. F.

How many lineal feet of 2-in. pipe will be needed for the cooling coils?

What capacity compressor will be required to do the work in 12 hr.? A. H. K.

Relation of Boiler to Engine Horsepower

WILL YOU tell me the boiler horsepower needed to supply a 24-hp. non-condensing engine using 60 lb. of steam per horsepower-hour? The boiler steam pressure is 96 lb. gage and the feed water temperature is 144 deg. F. W. J. M.

A. As 60 lb. of steam are consumed per hour for each horsepower, the total steam consumption of the engine is $60 \times 24 = 1440$ lb. per hr. As the steam pressure and feed water temperature are 96 lb. gage and 144 deg. respectively, the total heat per lb of steam.

$$H = xr + D = t + 32$$

Where x is the quality, r is the latent heat of evaporation, D is the heat of the liquid at 96 lb. and t is the feed water temperature. If we assume the quality to be 0.95, i. e., steam that is 95 per cent dry, we may find the total heat by substituting values as found in steam tables

$$H = 95 \times 881.9 + 306.2 - 144 + 32 = 1062 \text{ B.t.u.}$$

As the total heat of steam from and at 212 deg. is 970.4 B.t.u., the equivalent evaporation is $1062 \times 1440 \div 970.4 = 1578$ lb. per hr., and as one boiler horsepower is equivalent to the evaporation of 34.5 lb. of water from and at 212 deg. F., the boiler horsepower received to supply your engine will be $1578 \div 34.5 = 45.7$ hp.

Rate of Evaporation from a Water Surface

HOW SHOULD the amount of evaporation from a surface of still water in still air be figured, the temperature of the water being above that of the air and the relative humidity of the air being less than 100 per cent?

For example, take a 5-ft. diameter tank containing water at 155 deg. exposed to air at 50 deg. and 50 per cent relative humidity. The tank is exposed to the wind but the water level is a foot below the top of the tank. What would be the evaporation per hour?

What would be the radiation loss if the tank is 6 ft. high and made of 1½-in. wood staves? Also, what is the loss from a tank built up of ¼-in. steel plates?

L. K.

Cause of Excessive Steam Consumption

REPLYING TO M. P.'s inquiry in the April 1 issue of Power Plant Engineering regarding the high steam consumption of his non-condensing turbine, I would say that a dirty steam separator would undoubtedly increase the steam consumption by choking the inlet capacity of the turbine. Its effect would depend on the type of turbine, being greater for light loads on those with separate nozzle chambers which are successively opened by the governor than on those with a single nozzle or inlet chamber, the pressure in which is controlled by the throttling action of the governor valve.

If it is known that the turbine is getting dirty steam, part of the increased steam consumption may be due to the accumulation of dirt and sediment on the surface of the blading, roughening it and reducing the efficiency of the reaction of the steam on the blading, both by the friction of the steam passing over the dirt and the eddies in the flow caused by the change in the angle and area of the passages of the blading. If the accumulation is on the guide blading, it will result in loss due to excessive pressure drop through the nozzle passages and imperfect transformation of the heat energy of the steam into velocity energy, due to the incorrect form of the opening.

Increased steam consumption also results from the loss of blading in the turbine, but this is usually easily noticeable from the disturbance at the time the blading lets go, and also from excessive vibration of the tur-

bine, as such loss of weight would usually throw the rotor badly out of balance.

If the trouble is due to accumulation of dirt on the blading—which is not infrequent in the Middle West where there is considerable lime and magnesia in the water which is carried over, even through superheaters—the rotor must be removed and the blading scraped clean. Further accumulations can be prevented, once this has been done, by installing a regular condensation feed lubricator on the steam pipe ahead of the inlet valve and feeding about one-half pint of kerosene through it a day. In spite of the fact that it would seem that such a light oil would be completely vaporized at the average high pressure and superheat used, I have seen this worked successfully over a period of months and, where before the rotor required periodical cleaning, inspection showed no accumulation of dirt on the blading while kerosene was being fed. The kerosene had no effect on vacuum, condenser, pumps, or boilers.

Steam consumption of turbines designed for condensing operation is materially increased when operating non-condensing. In fact, with turbines of about the size under discussion, 600 kw., the total steam per hour remains practically constant and the power is reduced 40 to 50 per cent; that is, the steam consumption per kw.-hr. is increased by 67 to 100 per cent. I trust M. P. will let us know what he finds is wrong with his turbine.

Colver, Pa. H. D. FISHER.

Centrifugal Tension in Belting

I HAVE been interested in the various articles on the subject of centrifugal tension in belting which have been appearing in these columns of late. I notice that in most cases the illustrations used are simply sketches; it may add further interest to the subject to show a few examples of actual drives upon which the effects of centrifugal tension are shown to be present.

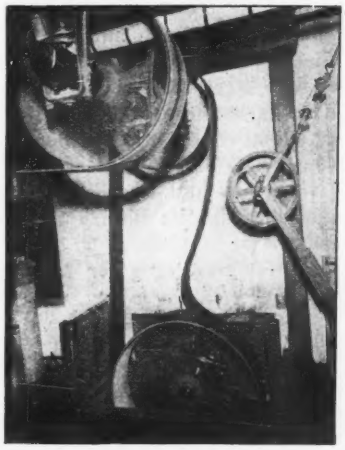


FIG. 1. VERTICAL DRIVE SHOWING HOW BELT IS WRAPPED AROUND DRIVER DUE TO CENTRIFUGAL ACTION

That shown in Fig. 1 is almost an exact parallel to the action indicated by Mr. Schaphorst in the March 1 issue. This drive, in Philadelphia, was the pet of the engineer and he took the trouble to lower the tightener upon starting in the morning, until the belt assumed the position shown, and then to remove the idler for the day's run. The belt is 14 in. wide and runs over 64-in. and 42-in. pulleys, 10 ft. on centers.

Figure 2 is a high speed 6-in. leather belt in a plant at Leipzig, Germany. It runs from a 6-in. driver (1400 r.p.m.) to an 11-in. driven pulley transmitting a load of 8 hp. Why some top pull belts, when run slack, will so clearly show the effects of centrifugal tension by wrapping the driving pulleys, while others of

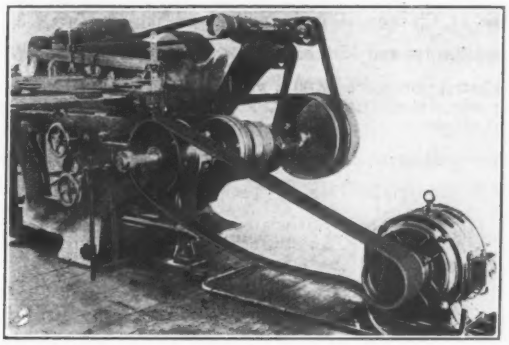


FIG. 2. PRACTICALLY HORIZONTAL DRIVE WITH TOP PULL, SHOWING TENDENCY TO HUG THE DRIVING PULLEY

practically equal speeds will not, perhaps some of your readers can explain.

Buffalo, N. Y. WILLIAM D. YOUNG.

Air Lift Pumping Equipment

I NOTE on page 391 of your April 1 issue, a request for an opinion on the use of air lift equipment for supplying water in large quantities.

Air lift equipment is well adapted to the pumping of large quantities of water from deep wells, ranging from 300 to 2000 ft. in depth. Commercial installations pumping water under these conditions average anywhere from 25 to 40 per cent efficiency. Until recently it has been difficult to obtain greater than this on shallow installations, that is, installations running less than 200 ft. in depth; however, it is possible at the present time to obtain an efficiency equal to that of an electric pumping installation for shallow depth.

Water lifted by means of air from the depth from which you are taking it at the present time should be pumped for a cost of about 1½ cents per 1000 gal., if the installation has been properly laid out and installed. I have used a foot piece, for which I have applied for a patent, in four wells pumping 2,000,000 gal. of water a day at an efficiency of approximately 54 per cent and at a cost of less than 1½ cents per 1000 gal.

Your question as to whether sewage could be handled by the air lift equipment instead of the steam pump can be answered positively. Not only will sewage be handled easily but in forcing the air through effluent matter, the air has a tendency to oxidize any organic matter present and to aerate it, purifying it so that it can be discharged into a body of water, which otherwise would be contaminated were the effluent not aerated. As far as sewage being handled economically with air lift in comparison to the steam pump, I would say that it can be done much more cheaply by the air lift.

Houston, Texas. H. N. SIMPSON.

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Engineers Should Be Given the Facts

In the past decade, there has been a marked change in the reaction of power plant engineers toward the arguments advanced by manufacturers in presenting the merits of equipment. In many cases, such arguments were founded on the idea that a competitor's equipment was mainly junk and glowing generalities were brought forward to convince the prospective buyer that a particular piece of apparatus was the best in its line.

Such tactics are not meeting with so much success at the present time, as engineers are seeking for the actual and unprejudiced facts on which to base their final decision. An artist's conception of a manufacturing establishment, showing a panorama that looks like the Gary plant of the United States Steel Corporation, when in reality the plant covers about a half an acre of ground, is not quite so impressive as it once was.

Even yet it is difficult for some of the old line manufacturers to realize the changing conditions, as can readily be ascertained by examination of trade literature. Frequently the conceit of the manufacturer is more evident than is any real desire to present technical information on the apparatus. After a careful perusal, the reader is more convinced that the organization is attempting to sell itself rather than its product.

After everything is said and done, a real engineer would rather buy something that is made by hand in a barn, if it served his purpose better, than the same article made in the artist's conception of a plant. Naturally the sound establishment of an organization enters into the final decision, since service requirements after an installation are important. Even this point, however, is not to be based on the size or the kind of a building the manufaeturer occupies, or necessarily on the basis of the number of years in business. If the latter point were a deciding factor, a new organization would never be able to get a start.

Fortunately the many manufacturers' associations are tending to raise the standard of arguments used against competing equipment, but there is even yet an improvement possible in the type of material presented in technical trade literature.

It is entirely possible and practicable to make such literature an actual contribution to the technical knowledge on a subject. Many manufacturers have appreciated this viewpoint and as a result their literature will be found filed in the library of the engineer as having some permanent value.

If the engineer is seeking for facts, why not give them to him?

From Our Rostra

Are you making the most of the opportunities that are afforded you? If these opportunities will in any way make your daily work easier or add zest to the performance of your routine duties, are you not passing up a bet by not taking advantage of them?

Take for example the service rendered by Power Plant Engineering in its "Letters," "Kinks," and "Problems" departments. Are you making use of this service as you might? These departments constitute our Rostra from which any reader is privileged to address his fellow readers on any topic pertinent to the subject of power plant engineering. These depart-

ments are the common property of our readers, developed and maintained for the intercommunication of ideas. You read the items presented in these columns and some of them you find of value in your particular line of duty; but if this is as far as you go, you are not obtaining the maximum benefit. The conduct of these departments is a mutual undertaking and like all such co-operative enterprises, the benefit derived is in direct proportion to the effort put into it.

Your method of doing certain things may be different from the other fellow's and he would like to hear about it just as you like to get his ideas on the subject. What new ideas or "kinks" have you evolved in installing new equipment or in repairing old? We are all interested in keeping equipment under our care in economical, reliable, and efficient operating condition. Perhaps your methods are a little different; if so, ascend our Rostra and tell us about it.

Have you a problem that is causing you some trouble? Why not ask your brother engineers about it? Perhaps someone has encountered and solved just such a problem as you are now confronted with. He can answer your question directly or show you the correct method of attack.

This Rostra is yours; make use of it.

Another Milestone for Standardization

Since its organization in 1919, the work of the American Engineering Standards Committee has been growing more important as the number of projects undertaken have increased. Sponsored by various engineering bodies to compile and co-ordinate standardizing work of the detached societies, it has grown into a body recognized by the entire industrial world.

It is quite natural that the average engineer should not be familiar with the work of such a body as the American Engineering Standards Committee because of the very nature of its organization and activity. This committee is in reality a clearing house for standards which may be sponsored by other bodies and brought to the attention of other organizations in this way. The final results are available to those interested and at the same time the American Engineering Standards Committee remains in a hazy background and takes little credit for the results.

The year book which has just been issued and which is commented on elsewhere in this issue stands as another milestone in the progress of standardization. Such work should be recognized as a great contribution to the advancement of engineering and industry.

Engineering Involves Economics

When an engineer takes charge of a power plant, he undertakes to operate and manage that plant in such a way as to make it a paying investment for the owner. The more he can make for the owner, the greater will be his success as an engineer. In other words, engineering in a power plant requires first of all a consideration of the economics involved.

Ordinarily the engineer speaks of the operation of equipment in terms of efficiency, the percentage of equivalent energy output he can get for a given input. Too frequently he stops here, apparently not realizing that his problem is only partially solved when he obtains the highest efficiency possible with the equipment available and the conditions of service which must be met.

Equipment becomes worn or deteriorated to such an extent that its efficiency is reduced and repair costs increase to an excessive amount. Progress may have been made in the design and manufacture of certain equipment that makes obsolete the equipment now installed, although practically as good as new.

By obsolete is meant uneconomical as compared to new equipment. To replace it will be a paying investment for the owner.

It must not be assumed, however, that because equipment is old and worn it would be to the financial advantage of the owner to have it replaced. There are just as definite ways of proving the economies of such a problem as there are of estimating next month's coal consumption. In too many plants the owner depends upon his accounting department for solutions to all economic problems, but unquestionably there are problems about the power plant that require more intimate knowledge of operation and equipment than can be expected of the best accountant.

In order to solve such problems, as pointed out elsewhere in this issue, the engineer needs records of past performance, repair and maintenance costs, he must know what new equipment will do in performance, cost of machinery installed, prevailing interest rates and reasonable life of machine. Then he is in position to solve this problem in economics which will prove whether or not an investment will be a paying proposition.

Compensated Motor Meets Difficult Driving Requirements

In certain classes of direct current motor drives, a very close speed regulation between light load and full load is required. Particularly in certain types of steel mill service, good speed regulating characteristics are of considerable importance in obtaining successful operation of the mill.

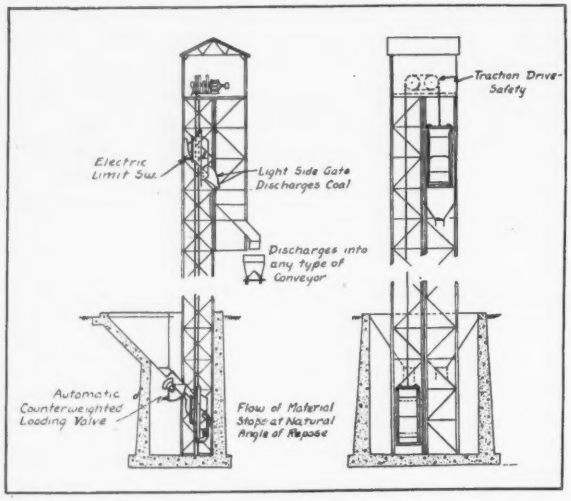
In cases of this kind where the requirements are comparatively rigid, the use of compensated direct current motors has been found highly satisfactory. With this type of motor, the pole faces are slotted and a winding known as a compensating winding is placed in them. This winding has a low resistance and is similar to the interpole winding of an interpole motor. The current in this winding flows in the opposite direction to that in the adjacent armature conductors, so that its effect is to neutralize the distorting influence of the armature current upon the main pole flux.

This type of motor, besides having good inherent speed regulation characteristics, also has high overload capacities, and, as pointed out by H. E. Stokes in an article on compensated motors in this issue, machines of this class have been built which have carried momentary peaks as high as eighteen times full load without disastrous consequences. It is evident, therefore, that the compensated motor has a distinct value, and, those having to do with motor drives where the conditions to be met are unusually severe, will find much of interest in Mr. Stokes' article.

POWER PLANT ENGINEERING DEVELOPMENTS AND NEWS

Skip Hoist Operates Automatically

FOR handling coal rapidly and efficiently the Maine Electric Co., of Portland, has brought out a traction drive type of skip hoist which is arranged for automatic operation. The loading gates are opened by the descending bucket; fill the bucket until the natural angle of repose stops the flow of material; are closed by the ascending bucket and held closed by counterweights.


Traction Drive-Safety
Electric Limit Sw.
Light Side Gate Discharges Coal
Discharges into any type of Conveyor
Automatic Counterweighted Loading Valve
Flow of Material Stops at Natural Angle of Repose

WHEN BUCKET REACHES THE TOP IT IS NOT TILTED BUT IS DUMPED THROUGH A SIDE OPENING GATE

When the bucket reaches the top of its travel, a side gate in the bucket is automatically opened and the material is discharged. This arrangement eliminates the necessity for tilting the bucket with its contents.

These skip hoists are built to be operated by any of the customary types of automatic push button control and are equipped with a full set of limit switches, overload relays and other protective devices to govern the skip properly. If desired, the skip can be made to start at the pressing of a button, hoist to the top, automatically stop, discharge, and await the pressing of another button by the operator; or they can be built to be started or stopped at will, but when once started continue to run up and down, allowing proper time at top and bottom for filling and emptying the buckets.

Protection against over-running is afforded by the traction type of drive, as the bucket which strikes the bottom of the pit relieves the tension on the ropes so that the bucket which is at the top cannot be hoisted beyond a predetermined point.

Boiler and Ash Hopper Built of Cast Iron

HANDLING and storing of ashes in boiler hoppers always presents a serious problem in boiler plant operation and maintenance. A careful selection of material and construction is required to overcome the

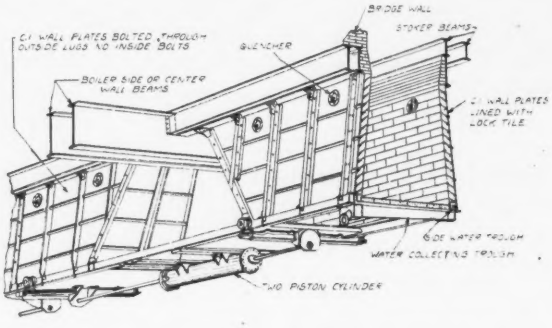

C.I. WALL PLATES BOLTED THROUGH OUTSIDE LUGS NO INSIDE BOLTS
BOILER SIDE OR CENTER WALL BEAMS
BRIDGE WALL
STOKER BEAMS
GUENCHER
C.I. WALL PLATES LINED WITH LOCK TILE
SIDE WATER TROUGH
WATER COLLECTING TROUGH
TWO PISTON CYLINDER

FIG. 1. TWO-PISTON CYLINDER OPERATES GATES ON ADJOINING BOILERS

effects of corrosion of hopper metal parts and abrasion due to clinker. Thorough and effective quenching of ash in the hopper is necessary; it may, however, become a source of wastage of water and a nuisance due to drippage. Ash gates and their operating mechanism must be simple in construction and positive in their action.

In Fig. 1 is shown the construction of a boiler ash hopper, gate and operating mechanism as developed by The Allen-Sherman-Hoff Co., of Philadelphia, Pa. The hopper frame is made of steel and is suspended directly from the boiler floor under framing. The lower longitudinal frame member is used as a track for the gate rollers and as a support for the cast iron gate frames.

All side and end plates are made of cast iron on account of the corrosive resisting properties of that material. The plates are provided with external recessed bolt lugs by means of which the plates are secured to the steel frame. This construction keeps the bolts outside the hopper, preventing contact with acidulous water. Each plate is provided with recessed and lapping edges so that when installed all joints are protected by lapping surfaces of cast iron. On the inner side of the wall plates are cast iron ledges, cast integral with the plates. These ledges support the tile lining so that each tile may be removed without disturbing the rest of the lining; further, these ledges make it impossible for the title to be dislodged during actual oper-

ation. The tile, which are of second quality, resist abrasion and spalling.

Ash gates are of cast iron with a refractory lining. Each gate is supported on four 5-in. rollers, the two rollers near the cylinder do not come under the gate opening at any time and therefore run on the inner track, the two opposite rollers run on the outside track; in this way they pass the gate opening and the difficulty due to ash deposit on the rail is overcome. Each

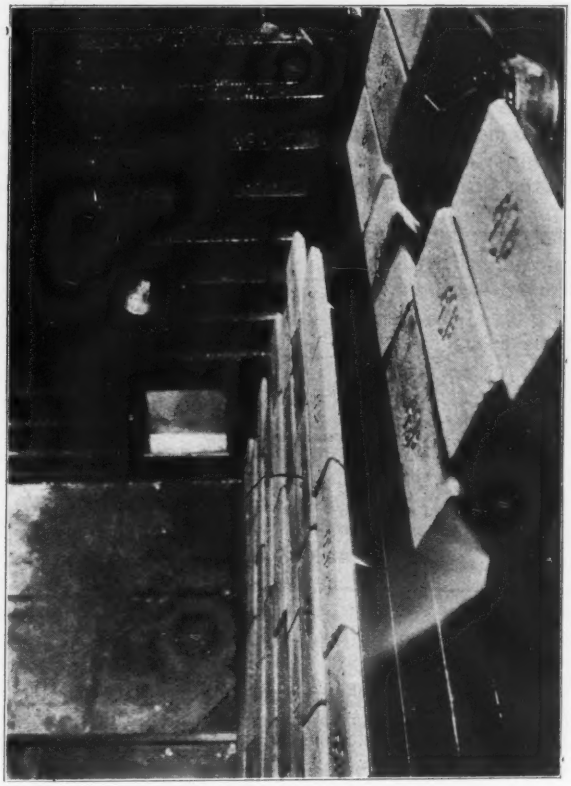


FIG. 2. INTERIOR OF ASH HOPPER LOOKING DOWNWARD SHOWING METHOD OF SUPPORTING TILE. NOTE QUENCHERS IN OPERATION

gate door is equipped with water troughs sloping to a stationary trough at the rear by means of which quenching water is collected and drained to waste.

Power or manual operation may be employed to move the gates. For power operation where boilers adjoin each other a two-piston air or steam cylinder is used, the piping of which is arranged to cushion the piston at the end of travel. Cast-iron ash quenchers may be provided which are novel in that all piping is outside the hopper walls and access plugs are conveniently located so that any individual quencher may be shut off and cleaned from the outside. The quencher orifice and access plug are of bronze.

In Fig. 2 is shown an interior view of a hopper in which some of the tile are in place and the quenchers in operation.

WORK has been started by the Idaho Power Co. on the new unit of the hydroelectric power plant at American Falls, on the east side of the Snake River. The new unit will consist of two 9000-hp. turbines operating at a 55-ft. head.

New Type Valve Has Rubber Seal

USERS of pumps will be interested to know that some changes in pump valve construction are now announced by the Worthington Pump and Machinery Corporation, of New York. An entirely different form of valve has been perfected which, when applied to service conditions that have been difficult for the older

FIG. 1. MEDIUM RUBBER VALVE AFTER THREE MONTHS COMPARED WITH SEAL VALVE AFTER A YEAR'S SERVICE

standard valves by causing them to cut and to leak, will eliminate both. It therefore increases the average pump efficiency; decreases the cost of pumping; and continually maintains the capacity of the pump at its maximum point.

After many years of building and operating pumps, the Worthington engineers have found that the princi-

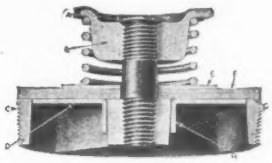


FIG. 2. BOTTOM PLATE AS A MIDDLE SEAT FOR THE RUBBER VALVE PROPER

pal cause of leakage is traceable to the excessive wear on the rubber, which, while negligible in some cases, is often quite bad. In the left-hand view in Fig. 1 is shown a photograph of a rubber valve after 3 mo. of particularly hard service. Cracks and cuts caused by the valve seat and by the radiating ribs are plainly visible. It is plain that the only way to positively prevent leakage with such ordinary valves in this condition is to remove and replace them with new valves.

To overcome this rapid and costly wearing, cutting and cracking action, the Worthington engineers have evolved the new type of valve shown in Fig. 2, known as the Worthington "Seal" valve for use when the conditions are too hard for the ordinary form of valves now in standard use.

This new valve assures absolute tightness when closed because, as will be noted, the rubber used is flexible and

will seat perfectly both at the hub and outer rim, its inner and outer seats, and so keep tight. Age and continuous usage do not cut grooves or cause cracks as demonstrated in the right-hand view of Fig. 1, which shows a flexible rubber seal used for one year in this new type of valve. At the end of the year, there was no visible wear; there was no leakage; renewal was, of course, unnecessary, and there was no cost for repairs.

In this new valve the feature of the design is in the bottom plate. This is in effect a middle seat for the rubber valve proper. When the valve is closed this middle seat carries the entire load and prevents the rubber seal from cutting on the seats or ribs. This bottom plate moves up and down with the rubber, and so not only acts as a middle seat, but this middle seat is movable with the rubber and helps to keep the rubber valve in shape even when open. Thus all mechanical functions requiring strength and wear resistance are cared for by metal parts. The flexible rubber acts only as a seal against leakage. It will be noticed that even the top of the rubber seal is protected by a thin "backing plate" which keeps the rubber seal flat and prevents any possibility of wear from contact with the spring.

Effect of Slackening Demand Shown in Coal Industry

BOTH the production of coal and the reserve stocks on hand have been affected by the falling off in demand for coal which has been felt in practically all the fields, if the surveys of Government agencies may be taken as indicative of the present status of coal conditions. Practically all large consumers seem to be proceeding with caution in buying for storage and the operators, on the other hand, have been curtailing production to meet the condition imposed by the lessening demands.

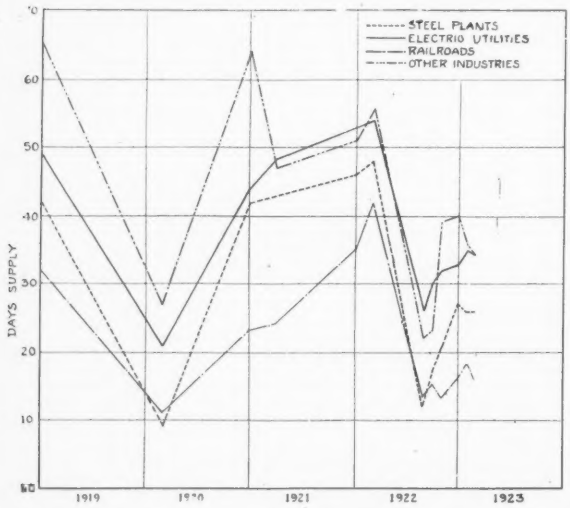


FIG. 1. STOCKS OF COAL ON HAND SHOW SHRINKAGE DUE LARGELY TO UNCERTAINTY OF MARKET CONDITIONS

On April 1 the office of the Federal Fuel Distributor completed a comprehensive survey which covered transportation, markets, prices and labor conditions in the principal bituminous fields. In almost every case market conditions are reported as demoralized, poor or fair. Prices have dropped off in some cases, but the operators maintain that with present costs as they are it is not likely that further reductions will be in order. The present reductions seem to be fairly in line with the usual seasonal prices which have been made in other years.

Transportation is reported as about 50 per cent normal; but since production had dropped off somewhat, most of the districts are able to get all the cars that are needed. In some sections of Pennsylvania, production is still held up by the transportation problem. The labor situation seems to be in fairly good shape, although it is reported that miners in some sections are leaving the mines for other work.

Points of interest brought out by the survey for some of the more important districts were as follows: In the Pittsburgh district shipments of lake coal have

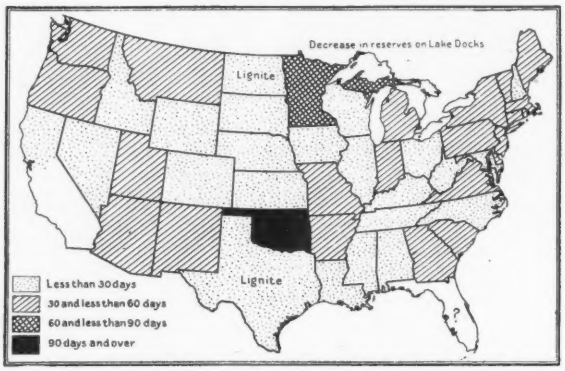

Decrease in reserves on Lake Docks
Lignite
Lignite
Less than 30 days
30 and less than 60 days
60 and less than 90 days
90 days and over

FIG. 2. DAYS' SUPPLY OF BITUMINOUS ON HAND AT INDUSTRIAL PLANTS ON MARCH 1, 1923

not begun, hence the demand is not nearly as strong as was several weeks ago. As soon as the lake season opens, it is expected that the demand will increase. Due more to the slow movement of cars than to car shortage, the car supply has been way below normal. A contract has been signed with the United Mine Workers of America, continuing the present scale until March 31, 1924, and there is no reason to anticipate any labor trouble before that date.

In central Pennsylvania, it is stated that there have been some contracts signed, but not nearly the volume that would be expected at this time, due probably to the view that prices may go lower. There has been a steady decline in prices since January. Operators believe that prices will go higher. This district has been loading about 18,000 cars a week, but 24,000 cars could be loaded if transportation conditions were better. For Northwestern Pennsylvania the conditions were found to be about the same, although the transportation seemed to be in somewhat better shape. Spot mine run prices ranged from $2.25 to $2.35 a ton. In Somerset County market conditions were poor, transportation unimproved and prices in many cases lower than the cost of production.

While the general situation in the West Virginia fields was found to be about the same as in other districts, there were two sections, Pocahontas and New River, which seemed to be in better shape than the others. There has been an increased demand for smokeless coal, particularly for tidewater shipment. Most of

the leading shippers have sold on contract all the coal they can reasonably expect to be able to deliver this year unless transportation is materially improved. There is quite a perceptible stiffening of prices for Pocahantas. Present prices for mine run range from $3.25 to $4 a ton. In the New River section there seems to be demand for more tonnage than the field can produce with its present car supply. Owing to the decline in prices at tidewater, this market is not so good as formerly and producers are taking more interest in the lake movement. The price of spot mine run is ranging from $3.50 to $4 a ton, but a stiffening in prices may be expected. Car supply is about 22 per cent of normal on one road.

In the Middle West the situation of Illinois coal is about the average of other fields through this part of the country. According to the survey substantial quantities of no-bill coal are accumulating on mine tracks, probably averaging in the neighborhood of 2000 cars standing each day. This is an average of 5 or 6 cars per shipping mine, of which there are 389 in this state. The majority of coal so held is in the prepared sizes, the demand for which continues to subside with the anticipated approach of warmer weather. The dealers meanwhile are disposing of their accumulations in order that they may not be compelled to carry over any coal that might be replaced at a lower price after the general market level for the dull months has become thoroughly established.

Screening are moving fairly well, and, as is also customary from mid-March to June 15, at somewhat higher prices, but still substantially below cost—an average in most fields of $1 or more less than the cost of production. Screening will doubtless advance both in demand and price, due to the limitation of production arising from recession in demand for prepared sizes. Steam users are not storing any coal, but, on the contrary, many are using up what storage they have on hand while others are buying from day to day just enough to supply current needs. Some mines have closed down because of no market.

Spring Meeting of A. S. M. E. Will Be Held at Montreal

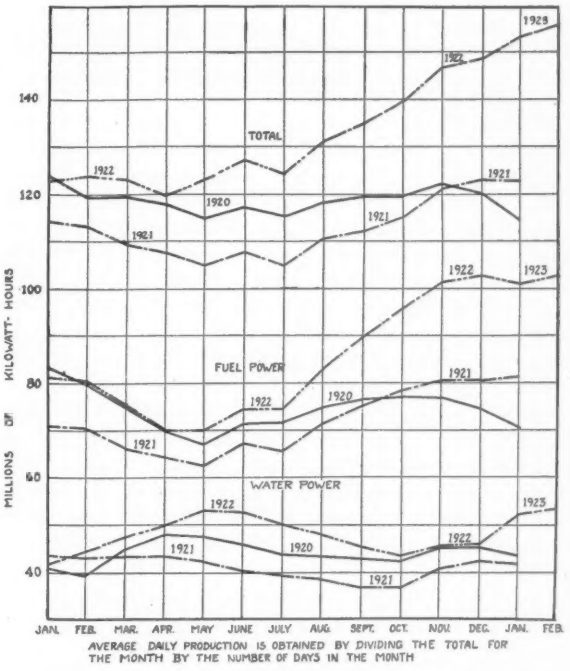
PLANS for the spring meeting of the American Society of Mechanical Engineers call for a four-day session, May 28 to 31, at Montreal, Quebec. A varied program covering power, machine shop practice, industrial methods and management problems has been announced.

On Monday, May 28, the sessions will be given over to business meetings and the papers of engineering interest will be taken up in the mornings of the days following. Three afternoons are allowed for excursions to points of interest and the evenings to social affairs.

Among the papers to be presented, the following are of particular interest to power plant engineers: Power Development in the Province of Quebec, by Julian C. Smith, and Development of Hydroelectric Power Plants in Ontario, by Fred A. Gaby. These two papers will be presented on the morning of May 29. At the power session on May 30, H. G. Acres will present a paper on Modern Hydraulic Turbines of Large Capacity and Payne Dean will talk on Sectionalization and Remote Control of High Pressure Steam Lines. On the morning of May 31, A. Cotton will present a paper on Chimney Design and O. P. Hood will discuss Lignite Char.

Production of Electricity Continues at Record Breaking Pace

AVERAGE daily production of electricity by public utility power plants continues to break all records as the average production in February was about 1½ per cent greater than that for January, according to the



AVERAGE DAILY PRODUCTION OF ELECTRICITY BY PUBLIC UTILITY PLANTS

U. S. Geological Survey. February is the seventh consecutive month which has established a new record of average daily output. The marked increase in the production of electricity during January and February of this year, as compared with the same period for 1922, is clearly shown by the curves of total output. All indications at the present time point to 1923 being a remarkable year in the production of electricity. The average daily output of electricity and the proportion produced by the use of water power for January and February were as follows: January, 153,200,000 kw.-hr., 34 per cent; February, 155,300,000 kw.-hr., 34.2 per cent. In January and February, 1922, the proportion produced by water power was 34 per cent and 35.2 per cent, respectively. It is also shown in this report that the consumption of fuel per kilowatt-hour has decreased about 22 per cent from 1919 to 1922. This is a remarkable achievement, the importance of which is readily recognized when it is considered that nearly 11,000,000 T. more of coal and its equivalent in other fuels would have been consumed in generating the electricity produced in 1922 by the use of fuel if the rate of consumption per kilowatt-hour had been the same as in

1919. A special endeavor should be made by public utilities to reduce still further the rate per kilowatt-hour in 1923.

Figures given in the report are based on returns received from about 3500 power plants each producing 10,000 kw.-hr. or more per month engaged in public service, including central stations, electric railways, and certain other plants that contribute to the public supply. The capacity of plants submitting reports of their operations is about 95 per cent of the capacity of all plants listed. The output of plants that do not report is estimated.

Work of American Engineering Standards Committee Growing

IN the year book which has just been sent out by the American Engineering Standards Committee there are listed 121 standardization projects which this committee has under way. Trade associations and general commercial bodies have shown decidedly increased interest in standardization work which in its earliest stages was considered of interest principally to engineers. While there are a large number of projects under way which have a definite interest to the power plant field, only a few of these have reached the point where standards have been issued.

It is possible, however, to secure pamphlets covering the following standards from the Superintendent of Documents at Washington by a small payment: Pipe Threads, Electrical Wiring and Apparatus in Relation to Fire Hazard, Electrical Safety Code, Rules for Electricity Meters and one on Methods for Sampling of Coal.

Standard of Interest to Power Plant Men

THERE are a number of other standards under way which will have a definite value to power plant engineers, such as the safety code for ladders, which is being sponsored by the American Society of Safety Engineers; Safety Code for Mechanical Refrigeration, which is backed by the American Society of Refrigerating Engineers, Safety Code for Mechanical Power Transmission Apparatus, Safety Code for Compressed Air Machinery, Safety Code for Electrical Power Control and a Ventilation Safety Code.

In connection with elevator standardization, it is the intention of the sponsor bodies which comprise the A. S. M. E., A. I. E. E., and the American Institute of Architects, to standardize as to capacities, sizes, methods of test and factors of safety for electrical passenger and material handling elevators of the traction type, including cars, counterweights, guides, ropes and control, signal, landing and doorway equipment, and the definition and determination of clearances for hatchway, penthouse, pits and machine rooms.

In the same way, the subject of identification of piping systems is being sponsored by the American Society of Mechanical Engineers and the National Safety Council. This work will involve the working out of a definite scheme for marking steam, gas, air, water, vacuum, refrigerating fluids and other similar pipes.

Safe operation and maintenance of conveyors and conveying machinery will also be covered and in connection with mechanical power control there will be a set of safety provisions for construction and operation of governors, clutches, belt shifters and other mechanical means of controlling power.

While the standardization rules of the American Institute of Electrical Engineers are quite widely known and recognized in the electrical field, at the same time the American Engineering Standards Committee has a number of projects which will still further work of this type. Terminal markings for electrical apparatus is being sponsored by the Electric Power Club, and the American Institute of Electrical Engineers is also sponsoring a study of ratings of electrical machinery and standardization of wires and cables. In this latter study, stranding and sizes of conductors, rubber, varnish, cloth, impregnated paper, enamel, cotton and silk insulation standards will be some of the points taken up.

How the Committee Functions

MEMBERSHIP in the American Engineering Standards Committee is made up of the various engineering societies, trade associations, and the various departments of the Government. The work of the committee is simply a systematic plan of co-operation by which all organizations interested in any particular standardization work participate, first, in deciding whether the work shall be undertaken at all; second, in formulating the standardization, and, third, in its ultimate approval as an American standard. The formula of each standard, including all detailed work and technical decisions, is in the hands of a working committee called a sectional committee. The sectional committee is made up of representatives designated by the bodies interested in a particular project. Each sectional committee is organized by and under the leadership of one or more of the principal bodies interested. Such bodies are known as "sponsors."

Since the Department of Commerce, with its division of simplified practice, is working along general standardization lines, the American Engineering Standards Committee has close co-operative relations with this division. The work on simplified practice, however, is somewhat broader than purely engineering standards, as it has more to do with the elimination of unnecessary types, sizes and lines of manufactured products.

Before the coming year's work is over, it is expected that a large number of new American standards will be issued. The procedure before a standard finally conducted calls for a preliminary draft after which the proposed standard is published for criticism, and is then finally submitted for adoption. After adoption, it is approved for issue and printed for distribution from the Superintendent of Documents at Washington.

Pacific Gas & Electric Co. to Spend $18,000,000

PACIFIC Gas & Electric Co. is preparing to spend between seventeen and eighteen million dollars in further hydroelectric development on the Pit River, and for transmission to load centers of the resulting power. The board of directors has approved plans for the construction, without delay, of another large power plant in the system, to be known as Pit No. 3, and

which, in its electric generating equipment, will represent in round numbers 100,000 hp. of installed capacity.

Pit No. 3 plant involves the construction of a diversion dam about 125 ft. high that will back the waters of the Pit River up approximately 8 mi., and by so doing will save something like 15 mi. of conduit which otherwise would have been necessary to construct in order to bring the water to the entrance of the tunnel. From this dam, then, the tunnel will be constructed some 22,700 ft. in length and of 3000 cu.-ft. per sec. water flow capacity. The outlet of the tunnel will be at a point about 300 ft. above the river and from that point the water will be sent surging down the penstocks into the power house to be constructed on a wooded flat on the river bank. The equipment of the power house will be, in round numbers, 100,000 hp. in installed capacity of generating apparatus.

Construction work will start in about 30 days. The first thing the company's engineers will do will be to extend the Pit River Railroad, which the company built 2 yr. ago, from Bartle into its Pit No. 1 development. The railroad will branch off at Cayton Valley, about 12 mi. on Bartle side of Pit No. 1 plant, and will follow the river in a southwesterly direction a distance of 5 mi. to the point marked for the dam site. The railroad will be at an elevation of 200 to 300 ft. above the stream and will be used for hauling supplies. Material, consisting mainly of compressors, steel rails and pipe, powder, lumber and camp equipment, will be lowered to the construction camp at the dam site by gravity. The railroad will be continued another 5 mi. to the power house site, following the course of the river.

In this way the Pacific Gas & Electric Co. enters upon the second important stage of its great Pit River development, which, when completed in power plants, tower lines, substations and general reinforcement and reconstruction of the company's distributing system all over its territory from the mountains of Shasta to the Bay of San Francisco, will entail an expenditure of about $100,000,000.

Less than five months ago the company placed in operation its hydroelectric plant known as Pit River No. 1, but in order to meet the growth of its business, now finds it necessary to proceed immediately with the construction of an additional plant on the Pit River with an approximate installed capacity of 100,000 hp. Funds are on hand to prosecute the work on this power plant during the present year and, also to take care of such other new construction that may be necessary in 1923 in the company's gas and other departments.

Co-ordination in the Plant

IT IS unfortunate that too few plants are really planned. (The same remark applies to churches, theaters, dwellings and stores.) There is too little attention paid to the relative importance of the various factors of location, environment and so on, to start with; and the relative capacities, actual and potential, of buildings and appurtenances; so that after operations have settled down, it is found that there are points of congestion in production or movement that limit both the capacity and the efficiency of the whole establishment. Good planning ahead would largely if not entirely prevent this.

ROBERT GRIMSHAW.

CO_2 Is Drawn Through Asbestos Filter

IN connection with Bulletin CO15, which has recently been issued by the Republic Flow Meters Co., of Chicago, covering its line of CO_2 meters, it will be noted that a change has been made in the method of drawing off the gas sample. The sample tube which is shown in the accompanying illustration consists of a perforated tube lined with asbestos. It is held in place by a

FILTER MAY BE WITHDRAWN BY REMOVING SQUARE PLUG

sleeve and flange, the flange being bolted to the wall. By removing the square plug, the filter may be removed for inspection or cleaning without disturbing the brickwork. The filter prevents dust from passing into the gas line, thereby eliminating the necessity of blowing out.

Power Projects to Open Up Huge Tract

APPLICATIONS of Lars Jorgensen, San Francisco engineer, for three major and three minor water power projects on the middle fork of the Feather River and upon which work will soon be started following approval already given by the Federal Power Commission, will result, say those behind the project, in the opening up of 120,000 acres and through a generating plant will develop 350,000 hp. The entire project will cost about $30,000,000. The state engineer and the state bonding commission have already approved the work.

Three water storage reservoirs and six hydroelectric plants have been planned. The Grizzly Valley reservoir will be the first to be constructed and will have a capacity of 90,000 acre ft. of water; another reservoir will be established on Buck's ranch and its capacity will be 70,000 acre ft., a third dam is to be erected on Gold Lake with a capacity of 19,000 acre ft. The Grizzly Valley dam will be 350 ft. long and 108 ft. in height. Application has been pending before the Federal Power Commission since September, 1921. Permission was granted after a thorough investigation by government authorities, it is said.

Oroville will be the principal city to be benefited by the new water and power scheme. It is expected that the power, which those behind the project say will be the cheapest in California, will bring to Oroville a score of new industries.

One of the first developments will be at Bean Creek, where 48,000 hp. will be developed at an estimated cost of about $5,000,000. At this point, the river falls at the rate of 200 ft. per mile, and the cost of impounding the water has been estimated at $5 an acre foot.

New Penn Central Plant Making Progress

PENN CENTRAL POWER CO., which operates an extensive transmission system in and around Altoona, Pa., has recently placed a large order for turbine-generator,

transformer, motor control, and switching equipment for installation in a new plant now in course of construction at Saxton, Pa. The order was placed through Day & Zimmerman, Inc., Philadelphia, Pa.

Initial installation in the new plant will consist of two 12,500-kv.a. Westinghouse turbine-generators, three-phase, 80 per cent power factor, 60-cycle, 13,200 v. These turbines will operate under a steam pressure of 250 lb. and 200 deg. superheat. Excitation will be supplied from direct connected exciters rated at 75 kw., 250 v., and there will be a 150-kw., 1200 r.p.m. turbine driven exciter for a spare.

Each turbine generator will have a 17,500-sq. ft. condenser and the two circulating pumps will be driven by 150-hp., three-phase, 2300-v., 575 r.p.m. squirrel cage motors. There will be two condensate pumps for each condenser, one turbine driven and the other motor driven.

Boiler equipment will consist of four 1100-hp. Stirling boilers, equipped with 11 retort stokers made by the Taylor Stoker Co. Each boiler will have two forced draft fans driven by 50-hp., three-phase, 2200-v., 1750 r.p.m. squirrel cage motors, and there will also be two 100-hp., three-phase, 2300-v., 1200 r.p.m. squirrel cage motors for driving the induced draft fans. The stokers will be driven by multi-speed squirrel cage motors rated at 15 hp. Speed corresponding to 6, 8, 12 and 16 poles will be obtained. The clinker grinder will be driven by a 5-hp. motor on the squirrel cage side, having speeds corresponding to 8 and 16 poles.

Electrically driven auxiliaries will be supplied either from a house turbine, which is rated at 750 kw., 80 per cent power factor, three-phase, 2300-v. or from a house transformer bank consisting of three 500-kv.a. transformers, 13,200 to 2300 v. The 2300-v. bus will be in duplicate, one bus being supplied by the house transformer, and the other by the house turbine. The two busses can be connected through reactors. Each 2300-v. power circuit will have two breakers so that it can be connected to either bus.

Federated Engineering Societies Will Make Coal Survey

IT IS announced by the Federated Engineering Societies that W. L. Abbott, of Chicago, has been appointed as chairman of a committee to make a nation-wide coal storage survey in co-operation with the United States Coal Commission and the Department of Commerce. Other members of the committee will be named in the near future.

It is probable that the personnel will represent many groups, including coal mining, both bituminous and anthracite; transportation, public utilities, U. S. Bureau of Mines, chemical engineering, economics and equipment. It is proposed to complete the survey by Nov. 1 of this year.

Chairman Abbott is a member of the American Institute of Electrical Engineers and has been a leader in the engineering movement for government reorganization sponsored by the National Public Works Department Association.

Chairman John Hays Hammond, of the coal commission, believes that the engineers of the country are in a particularly advantageous position to aid the commission, according to President Mortimer E. Cooley. The question of engineering co-operation has been referred to the member societies of the federation, and the response has been encouraging.

News Notes

DETROIT STOKER CO. announces the appointment of Nelson G. Phelps as district manager of its New York office at No. 2 Rector St., New York.

EXECUTIVE OFFICES of the Midwest Steel & Supply Co. have been removed from 28 W. 44th St., New York, to larger quarters at 100 E. 45th St.

SUPERHEATER CO. of New York City announces that J. S. Cothran, Charlotte, N. C., has been appointed representative of the company for North Carolina and South Carolina.

CHARLES H. ADAMS, formerly assistant chief engineer of the El Paso (Texas) Electric Railway Co., has joined the organization of the Columbus Electric and Power Co., Columbus, Ga., where he will be chief engineer of the steam plant of that system.

CONVEYORS CORPORATION of America, Chicago, Ill., announces the appointment of Irvin C. De Haven Engineering Corporation, Indianapolis, as district representatives. The new agency will handle the sale of the American steam jet ash conveyor in Indianapolis and the surrounding territory.

COMBUSTION ENGINEERING Corporation and the Uehling Instrument Co. have recently entered into an agreement whereby Uehling interests in the Dominion of Canada and Newfoundland will be handled exclusively by the Combustion Engineering Corporation, with principal offices located in Toronto, Montreal, Winnipeg and Vancouver.

OPENING of a Philadelphia office is announced by Dwight P. Robinson & Co., engineers and constructors. The new office will be under the direction of Carl A. Baer, member American Institute of Electrical Engineers, who was recently with the firm of Baer, Cook & Co., engineers, and a consulting engineer in the design of industrial, textile and power plants.

PORTLAND RAILWAY, LIGHT & POWER CO. has awarded to the Pelton Water Wheel Co. contracts for furnishing the following valves for its Oak Grove project: a 72-in. butterfly valve at the lower end of the penstock, a 72-in. Johnson valve at the upper end, and a relief valve for the turbine itself. This turbine which is a vertical unit and will develop 35,000 hp. under a head of 850 ft., is now under construction at the Pelton shops. It will be the highest head reaction turbine in the world.

PLANS WERE announced recently for the ultimate expenditure of $10,000,000 on a generating plant on the Houston ship canal by Judge E. B. Parker, president of the Houston Lighting & Power Co. Excavation for the first unit has been started on a 98-acre tract fronting 1250 ft. on the channel below the turning basin. The first unit will be a plant with two turbines, each generating 20,000 kw. It will cost $4,000,000. Three more units of like capacity are projected, Judge Parker disclosed. The ultimate capacity will be 160,000 kw.

TOM P. WALKER has taken up new duties as manager of the Baton Rouge Electric Co., Baton Rouge, La.

Mr. Walker has been manager of the Haverhill (Mass.) Gas Light Co., and is succeeded there by J. L. Alexander, formerly manager of the Keokuk Electric Co., Keokuk, Iowa. The companies included in these changes are under the management of Stone & Webster, Inc., and Walter H. Burke, who has been in the Boston office of that organization for several years, will succeed Mr. Alexander as manager in Keokuk.

OFFICIALS OF the Tennessee Electric Power Co. have announced that plans are being made for the erection of a 30,000-hp. steam plant at Hale's bar, the completed development to cost approximately $1,500,000.

PLEA FOR another bond issue of probably $35,000,000 for additional municipal hydroelectric power development and distribution is under consideration for the June ballot by the Bureau of Power and Light of Los Angeles. The last power bond issue was in 1919 when the voters authorized an issue of $13,500,000 of which $11,000,000 was to purchase the Los Angeles distributing lines of the Southern Califorina Edison Co., and $2,500,000 was to be for the construction of new power plants and for extending distributing lines.

JOSEPH BOWES has been made general light and power superintendent of the Eastern Texas Electric Co., which is under Stone & Webster management. For the past 6 yr. Mr. Bowes has been superintendent of the Port Arthur division of the company. He will make his new headquarters in Beaumont, Texas, and is succeeded at Port Arthur by S. P. MacFadden, formerly secretary in the Texas district office of Stone & Webster, Inc. F. C. Taylor, formerly chief engineer of the Eastern Texas Electric Co. has been appointed superintendent of power stations.

PHILIP I. ROBINSON, who was recently appointed manager of the Baton Rouge (La.) Electric Co. by Stone & Webster, Inc., died on March 22 after an operation for appendicitis. Mr. Robinson was born in Waterville, Maine, in 1886, and graduated from the University of Maine in electrical engineering, in 1908. He entered the Boston office of Stone & Webster, Inc., and after spending some time in that office was transferred to the Light & Traction Co. at Houghton, Mich. From his position there he was promoted to be manager of the Fort Madison (Iowa) Electric Co. in December, 1917.

CONSTRUCTION has been started by Dwight P. Robinson & Co., Inc., on an extension to the "South Power Station" of the Aliquippa Works of the Jones & Laughlin Steel Corporation near Woodlawn, Pa. The improvement includes preparation of site, foundations and condenser well, and the erection of an extension to the building to house a 10,000-kw. steam generator unit with condenser and all other appurtenances. The installation of a new turbine driven pump in the pump house, with connections to steam and water mains, is also included.

NEW ENGLAND POWER CO., which is constructing a large reservoir at Whitingham, Vt., to provide power for municipalities and industries of central and western Massachusetts, has petitioned the Massachusetts Public Utilities Commission for permission to issue stock to the amount of $3,000,000 to finance the extensions proposed by the company. The proposed work includes construction of a 75-mi. high power line from Davis Bridge, Vt., to Millbury, Mass., the line to carry 110,000 v.; the building of a sub-station at Lanesboro and the construction of tributary power lines. Construction work on the new dam has been started again with the advent of spring weather and work will be pushed forward as fast as possible to completion. It is expected that by late summer much of the work will be completed.

COAL PRODUCERS and consumers who attend the eleventh annual meeting of the Chamber of Commerce of the United States in New York, May 7 to 11, will be given a special opportunity to discuss the coal problem as the entire session of the Natural Resources Production group will be given over to that subject. Details of the group meeting program, announced by W. DuB. Brookings, manager of the Natural Resources Production Department of the National Chamber, indicate that three aspects of the coal situation will be covered in the addresses scheduled to precede the general discussions. The program follows: "Some Problems of Coal Distribution," by J. D. A. Morrow, president, Morrow Callahan Coal Co.; "Labor and Its Relation to the Cost of Industrial Coal," by J. G. Bradley, president Elk River Coal & Lumber Co.; "Economic vs. Legislative Solution of the Coal Problem," by George H. Cushing, editor, "Cushing Survey."

U. S. CIVIL SERVICE COMMISSION announces the holding of open competitive examinations, throughout the country on May 9, 10 and 11, for the position of assistant examiner, for duty in the United States Patent Office, Washington, D. C. Successful contestants will be given an entrance salary of $1500 a year, plus the increase of $20 a month granted by Congress. There is provision for promotion to positions paying as high as $3900 a year. In addition to present vacancies, 43 new positions are authorized, effective July 1.

Competitors will be examined in the subjects of physics, mechanical drawings, technics, mathematics, language (French and German), and optional subjects. Applicants must select one of the following optional subjects: Electro-chemistry, general chemistry, or chemical, civil, electrical, and mechanical engineering. On account of the urgent need for assistant examiners, the examination papers will be rated and certification of eligibles made within the shortest possible time after holding the examination. Full information and application blanks may be obtained from the United States Civil Service Commission, Washington, D. C., or the secretary of the board of U. S. civil service examiners at the postoffice or customhouse in any city.

Books and Catalogs

AMERICAN SOCIETY OF HEATING AND VENTILATING ENGINEERS GUIDE—VOL. 1, 1922; 360 pages 6 by 9 in., cloth; New York.

At the meeting of the Illinois Section of the American Society of Heating and Ventilating Engineers in Chicago, March 12, J. A. Cutler of the Guide Committee of this section made a plea for the support of the Guide by the members, asking them to contribute to the data section and to make its value known to both prospective users and advertisers. He went on to say that the Guide is the only volume containing accurately compiled data on

heating and ventilating practice and should be of interest to everyone interested in this subject. It contains reference tables useful in the design and construction of heating and ventilating installations compiled from the transactions of the society, the investigations of its research laboratory, and the practice of its members, together with a catalog and reference data section comprising facts about manufacturers' equipment.

It was started last year as a means of promoting the use of modern equipment used in this field and to supply a reliable reference on this subject. The main function of the Guide is to diffuse throughout the country the influence of the society—leading to better engineering and better equipment.

The text section in part contains reports of various committees on the subjects of Flanged Fittings and Flanges, Use of the Pitot Tube, Code for Testing Heating Systems, Synthetic Air Chart, Code for Testing Low Pressure Heating Boilers, Code for Testing Direct Radiation Heating Plants, Standard Sizes of Steam and Return Mains, Code of Ethics, Automatic Heat Control, Construction of Chimneys, High Temperature Drying, Water Pipe Sizes and Warm Air Furnace Heating.

The General Data Section contains such chapters as Heat Losses from Buildings, Transmission Constants for Building Materials, Selection of Radiation, Heat Transmission from Radiators, The Boiler and its Care and Operation, Chimneys, Pipe Sizes for Steam Heating, Flow of Steam in Pipes, Pipe Sizes and Connections, Dimensions and Capacities Steam Vacuum Pumps, and Psychrometric Charts and Tables.

For the next volume sub-committees have been appointed to prepare data on the following subjects:

Air Conditioning	Lead Lined Pipe
Blast Heating	Pump Data
Cast Iron Pipe	Refrigeration
Copper and Brass Pipe	Steam Heating
Recirculating Systems	Steel Pipe
Fan Ventilation	Temperature Regulation
Gas Heating	Ventilators
Hot Water Heating	Warm Air Furnaces
Insulation	Wrought Iron Pipe

MIDWEST AIR FILTERS, which were described in the March 1 issue of Power Plant Engineering, are covered in a folder recently issued by the Midwest Steel & Supply Co., of New York City.

IN A COMPREHENSIVE 176-page catalog, No. 21, Golden-Anderson Valve Specialty Co., of Pittsburgh, Pa., has described its entire line of steam and water specialties. Among these many specialties are automatic valves for high and low pressure steam and water service.

KEEPING SCALE OUT of your boilers is taken up in a new bulletin issued by the Wayne Tank & Pump Co., of Fort Wayne, Ind. In the discussion it is shown how the water is softened by the Wayne system which is of the general Zeolite process. Some of the causes for foaming or priming of boilers are given.

IN AN 84-PAGE catalog, No. 1006, recently issued by the Bristol Co., of Waterbury, Conn., the line of recording gages for pressure and vacuum built by this organization are illustrated and described. It is pointed out that all ranges from full vacuum to 12,000 lb. pressure per square inch can be taken care of by these gages and that they are adapted for pressure of liquids, gases, steam or air. Through the use of an electrical transmitting system, which is also illustrated, it is possible to record pressures and water levels at a distance of several miles.

OPERATING INSTRUCTIONS for the Hays gas analyzer are presented in a bulletin which is now being distributed by the Jos. W. Hays Corporation, of Michigan City, Ind. The bulletin gives in detail the construction and operation of the analyzer which is used for testing flue gases and regulating conditions to give efficient combustion of the fuel. The manipulation is given in detail with sketches and illustrations to supplement the text.

STATEMENT OF THE OWNERSHIP, MANAGEMENT, CIRCULATION, ETC.,

required by the Act of Congress of August 24, 1912, of Power Plant Engineering, published semi-monthly, at Chicago, Ill., for April 1, 1923.

State of Illinois
County of Cook
ss.

Before me, a Notary in and for the state and county aforesaid, personally appeared Charles S. Clarke, who, having been duly sworn according to law, deposes and says that he is the Secretary of the Power Plant Engineering, and that the following is, to the best of his knowledge and belief, a true statement of the ownership, management (and if a daily paper, the circulation), etc., of the aforesaid publication for the date shown in the above caption, required by the Act of Aug. 24, 1912, embodied in section 443, Postal Laws and Regulations, printed on the reverse of this form, to-wit:

1. That the names and addresses of the publisher, editor, and business managers are:
Publisher, Technical Publishing Co., Chicago, Ill.
Editor, Arthur L. Rice, Chicago, Ill.
Managing Editor, none.
Business Manager, E. R. Shaw, Chicago, Ill.

2. That the owners are: (Give names and addresses of individual owners, or, if a corporation give its name and the names and addresses of the stockholders owning or holding 1 per cent or more of the total amount of stock.)
Technical Publishing Co., Chicago, Ill.
E. R. Shaw, Chicago, Ill.
A. L. Rice, Chicago, Ill.
K. L. Rice, Chicago, Ill.
Charles S. Clarke, Chicago, Ill.

3. That the known bondholders, mortgagees, and other security holders owning or holding 1 per cent or more of total amount of bonds, mortgages, or other securities are: (If there are none, so state.)
There are none.

4. That the two paragraphs next above, giving the names of owners, stockholders, and security holders, if any, contain not only the list of stockholders and security holders as they appear upon the books of the company but also, in cases where the stockholder or security holder appears upon the books of the company as trustee or in any other fiduciary relation, the name of the person or corporation for whom such trustee is acting, is given; also that the said two paragraphs contain statements embracing affiant's full knowledge and belief as to the circumstances and conditions under which stockholders and security holders who do not appear upon the books of the company as trustees, hold stock and securities in a capacity other than that of a bona fide owner; and this affiant has no reason to believe that any other person, association, or corporation has an interest, direct or indirect, in the said stocks, bonds, or other securities than as so stated by him.

5. That the average number of copies of each issue of this publication sold or distributed, through the mails or otherwise, to paid subscribers during the six months preceding the date shown above is..... (This information is required from daily publications only.)

Chas. Sanford Clarke, Secretary

Sworn to and subscribed before me this 26th day of March, 1923. Gertrude M. Williams,
(SEAL) (My commission expires August, 12, 1925.)

NOTE.—This statement must be made in duplicate and both copies delivered by the publisher, to the postmaster, who shall send one copy to the Third Assistant Postmaster General (Division of Classification), Washington, D. C., and retain the other in the files of the postoffice. The publisher must publish a copy of this statement in the second issue printed next after its filing.

Sparks from the Advertising Pages

Where Buyers and Sellers Meet

Uncle Sam Cashes In

A manufacturer recently said to a representative of POWER PLANT ENGINEERING: "That lathe turns out the work in one-tenth the time it took us before we had it. But we couldn't have owned one for some years except that we saw a chance to buy one cheap from the War Department.

"You see, we don't have enough work of this class to keep a lathe busy all the time. This lathe was built to work on shells during the war and has a very limited use.

"We purchased it at a price low enough to make it a paying investment for the part time we can use it; the War Department disposed of it for cash when most machine shops had no use for it. It is exactly what we need for we are now able to make our product better and at a lower price."

The product this manufacturer makes is one that will save time and money for every operator of power plant machinery and yet it is a device which it is possible to do without.

It is now advertised in these pages more forcefully than ever and more and more power plants are adopting it, profiting by the lower price at which it is being sold and by the savings it continuously effects.

Thinking men are coming to believe that waste is only matter out of place and the above is only a minor incident in clearing up the after waste of the world's most wasting war.

From time to time you have seen the War Department's advertisements in this and other publications, and in the April 1st issue was told something of the story of how a billion dollars has been reclaimed for the treasury through the sale, proper distribution and use of surplus war materials.

At the recent meetings and exhibit under the joint auspices of the Chicago Business Papers Association and Advertising Council, Major J. L. Frink brought out other points in the government's sales campaign.

When the sales department first organized lists of names were circularized. Then came the present campaign of advertising, the plan for which is credited to the business papers.

Before advertising, $368,000 was the best bid on one plant that was up for disposal. It was advertised at a cost of $4,000, as a result of which the government realized $100,000 more than the best previous offer on this one plant. For every $4 spent in advertising the government received $100 over and above what it would have received for the property without advertising.

The entire cost of all the government's advertising in the business press and other publications has been less than one cent for every dollar of sales, a remarkable record.

Advertising, like every business transaction, whether it be the sale of a day's work, an engine or a shingle nail, must be conducted on a basis that is profitable to the buyer, the seller and the public.

Society as a whole must benefit by any business or institution that is to survive. Never is there a matter between the buyer and seller alone.

To have written off the entire cost of war; to have junked all surplus material might have been the quickest way out of the business situation of four years ago.

Coal, ore and the life of men were tied up in that lathe referred to above, resources which can never be replaced. Taxes taken directly or indirectly from every man, woman and child were tied up in it.

To have thrown this great quantity of surplus material on the market at any price would have closed up foundries, mills, banks and offices without number and thrown millions of more people out of work.

Now that business is active, mills running and men employed from one end of the land to the other we can see the War Department's wisdom in employing the great force of advertising.

It has reclaimed hundreds of millions of dollars for the treasury. It has put back into service machines, equipment and supplies representing mountains of raw material. It has speeded removal of the menace of idle machines and unused goods which hung over manufacturers in every line.

It has helped, as in the case of the lathe, to reduce costs and make more efficient the processes of other manufacturers, a movement which, once started, distributes benefit to increasing numbers until at least some profit is passed on to society as a whole—which is only another name for all of us.

Last, but not least, this great distribution of surplus products to those who could find a use for them has been brought about at a cost for advertising of less than one per cent of the sale price.

It might have been done in many different ways, but surely in no way where the cost was so low.

Machinery, Equipment and Supplies Used In The Production and Transmission of Power

Under the heading of each product listed will be found the names of the manufacturers of that product. The index to advertisers, next to the back cover, gives the page numbers on which the manufacturers' descriptive advertisements appear.

AIR COMPRESSORS.
Allis-Chalmers Mfg. Co., Milwaukee, Wis.
Bury Compressor Co., Erie, Pa.
Dean Bros. Co., Indianapolis, Ind.
De Laval Steam Turbine Co., Trenton, N. J.
Gardner Governor Co., Quincy, Ill.
Ingersoll-Rand Co., New York.
Worthington Pump & Machinery Corp., New York, N. Y.
Yeomans Bros. Co., Chicago, Ill.

AIR FILTERS.
Midwest Steel & Supply Co., Inc., New York, N. Y.

AIR WASHERS.
Badger & Sons Co., E. B., Boston, Mass.
Cooling Tower Co., Inc., The, New York.
Spray Engineering Co., Boston, Mass.

ALARMS, HIGH AND LOW WATER.
Hills-McCanna Co., Chicago, Ill.
Huyette Co., Inc., The Paul B., Philadelphia, Pa.
Northern Equipment Co., Erie, Pa.
Reliance Gauge Column Co., Cleveland, Ohio.

ARCHES, BOILER COMBUSTION.
Betson Plastic Fire Brick Co., Inc., Rome, N. Y.
Detrick Co., M. H., Chicago.
Green Engineering Co., E. Chicago, Ind.
Harbison - Walker Refractories Co., Pittsburgh, Pa.
Jointless Fire Brick Co., Chicago.
Liptak Fire Brick Arch Co., Chicago, Ill.
McLeod & Henry Co., Troy, N. Y.
Quigley Furnace Specialties Co., Inc., New York.

ASH CONVEYING SYSTEMS.
Brown Hoisting Machinery Co., The, Cleveland, Ohio.
Conveyors Corp. of Amer., Chicago.
Detrick Co., M. H., Chicago.
Green Engineering Co., E. Chicago, Ind.
Jeffrey Mfg. Co., The, Columbus, Ohio.
Link-Belt Co., Chicago, Ill.
Stephens-Adamson Mfg. Co., Aurora, Ill.
Webster Mfg. Co., The, Chicago.

BABBITT METAL.
Magnolia Metal Co., New York.
Scully Steel & Iron Co., Chicago.

BAROMETERS.
Taylor Instrument Cos., Rochester, N. Y.

BEARING METAL.
Magnolia Metal Co., New York.
Strong, Carlisle & Hammond Co., The, Cleveland, O.

BELT CONVEYORS.
Brown Hoisting Machinery Co., The, Cleveland, Ohio.
Jeffrey Mfg. Co., The, Columbus, Ohio.
Portable Machinery Co., Passaic, N. J.
Stephens-Adamson Mfg. Co., Aurora, Ill.
Webster Mfg. Co., The, Chicago.

BELT DRESSING.
Cling-Surface Co., Buffalo, N. Y.
Crandall Packing Co., Palmyra, N. Y.
Dixon Crucible Co., Jos., Jersey City, N. J.
Stephenson Mfg. Co., Albany, N. Y.

BELTING.
New York Belting & Packing Co., New York, N. Y.
Pioneer Rubber Mills, San Francisco, Cal.
Quaker City Rubber Co., Phila.
Voorhees Rubber Mfg. Co., Jersey City, N. J.

BELTING, SILENT CHAIN.
Link-Belt Co., Chicago, Ill.

BELT LACING.
Bristol Co., The, Waterbury, Conn.
Detroit Belt Lacer Co., The

BLOWERS, FAN AND FURNACE.
Carling Turbine Blower Co., Worcester, Mass.
Coppus Engineering Corp., Worcester, Mass.
De Laval Steam Turbine Co., Trenton, N. J.
Ingersoll-Rand Co., New York.
Perfection Grate & Supply Co., Springfield, Mass.
Sturtevant Co., B. F., Boston.
Terry Steam Turbine Co., The, Hartford, Conn.
Wing Mfg. Co., L. J., New York.

BLOWERS, STEAM.
McClave-Brooks Co., Scranton, Pa.
Schutte & Koerting Co., Phila.

BLOWERS, TURBINE.
Carling Turbine Blower Co., Worcester, Mass.
Moore Steam Turbine Corp., Wellsville, N. Y.

BLOWERS, TUBE.
Bayer Co., The, St. Louis, Mo.
Diamond Power Specialty Corp., Detroit, Mich.
Marion Mach., Fdry. & Supply Co., Marion, Ind.
Pilley Pkg. & Flue Brush Mfg. Co., St. Louis, Mo.

BOILER BAFFLES.
Betson Plastic Fire Brick Co., Inc., Rome, N. Y.
Engineer Co., The, N. Y.
Johns-Manville, Inc., New York.
Jointless Fire Brick Co., Chicago.
King Refractories Co., Inc., Buffalo, N. Y.
Quigley Furnace Specialties Co., Inc., New York, N. Y.

BOILER CAP CLEANERS.
Paragon Power Specialties Co., Hartford, Conn.

BOILER COMPOUND.
Boiler-Kote Co., The, Chicago.
Dearborn Chemical Co., Chicago.
Hawk-Eye Compound Co., Blue Island, Ill.
Paige & Jones Chem. Co., Chicago, Ill.

BOILER COMPOUND FEEDERS.
Hills-McCanna Co., Chicago, Ill.

BOILER COVERING.
Celite Products Co., New York.
Quigley Furnace Specialties Co., Inc., New York, N. Y.

BOILER FEEDWATER PURIFYING APPARATUS.
Graver Corp., E. Chicago, Ind.
Griscom-Russell Co., New York.
Paige & Jones Chem. Co., Chicago, Ill.
Permutit Co., The, New York.

BOILER MOUNTINGS.
Lunkenheimer Co., Cincinnati.

BOILERS.
Babcock & Wilcox Co., N. Y.
Badenhausen, Phillips, Philadelphia, Pa.
Brownell Co., The, Dayton, O.
Casey-Hedges Co., The, Chattanooga, Tenn.
Connelly Boiler Co., The D., Cleveland, O.
Edge Moor Iron Co., Edge Moor, Del.
Erie City Iron Works, Erie, Pa.
Freeman Mfg. Co., Racine, Wis.
Keeler Co., E., Williamsport, Pa.
Page Boiler Co., Chicago, Ill.
Union Iron Works, Erie, Pa.

BOILER SEAM PROTECTORS.
National Boiler Protector Co., Dayton, Ohio.

BOILER SETTING CEMENT.
Betson Plastic Fire Brick Co., Inc., Rome, N. Y.
Harbison - Walker Refractories Co., Pittsburgh, Pa.
Huyette Co., Inc., The Paul B., Philadelphia, Pa.
Jointless Fire Brick Co., Chicago.
King Refractories Co., Inc., Buffalo, N. Y.
Quigley Furnace Specialties Co., Inc., New York, N. Y.

BOILER SETTINGS.
Betson Plastic Fire Brick Co., Inc., Rome, N. Y.
Harbison - Walker Refractories Co., Pittsburgh, Pa.
Jointless Fire Brick Co., Chicago.
King Refractories Co., Inc., Buffalo, N. Y.
McLeod & Henry Co., Troy, N. Y.
Quigley Furnace Specialties Co., Inc., New York, N. Y.

BOILER SKIMMERS.
Sims Co., The, Erie, Pa.

BOILER TUBES.
Scully Steel & Iron Co., Chicago.

BOILER WALL COATINGS.
Boiler-Kote Co., The, Chicago.
Johns-Manville, Inc., New York.

BOOKS AND SCHOOLS.
Audel, Theo., & Co., New York.
Hays School of Combustion, Chicago, Ill.
Stumpf Una-Flow Engine Co., Inc., Syracuse, N. Y.

BRIDGE CRANES, ORE AND COAL HANDLING.
McMyler-Interstate Co., The, Cleveland, Ohio.

BRUSHES, DYNAMO & MOTOR.
Dixon Crucible Co., Jos., Jersey City, N. J.

To Find the Manufacturers' Advertisements of Products Listed Here, See Index Page 162

BRUSHES, GRAPHITE.
Dixon Crucible Co., Jos., Jersey City, N. J.

BRUSHES, WIRE.
Pilley Pkg. & Flue Brush Mfg. Co., St. Louis, Mo.

BUCKET ELEVATORS.
Brown Hoisting Machinery Co., The, Cleveland, Ohio.
Link-Belt Co., Chicago, Ill.
Webster Mfg. Co., The, Chicago.

BUCKETS, CLAMSHELL.
Brown Hoisting Machinery Co., The, Cleveland, Ohio.
McMyler-Interstate Co., The, Cleveland, Ohio.

BUCKETS, ORANGE PEEL.
McMyler-Interstate Co., The, Cleveland, Ohio.

CALORIMETERS, GAS RECORDING.
Precision Instrument Co., Newark, N. J.

CARRIERS, PIVOTED BUCKET.
Webster Mfg. Co., The, Chicago.

CASTINGS.
Fuller-Lehigh Co., Fullerton, Pa.
Hills-McCanna Co., Chicago, Ill.
Hooven, Owens, Rentschler Co., The, Hamilton, Ohio.
Neemes Bros. Inc., Troy, N. Y.

CEMENT, ASBESTOS.
New York Belting & Packing Co., New York, N. Y.

CEMENT, HIGH TEMPERATURE.
Boiler-Kote Co., The, Chicago.
Harbison - Walker Refractories Co., Pittsburgh, Pa.
Jointless Fire Brick Co., Chicago.
King Refractories Co., Inc., Buffalo, N. Y.
Quigley Furnace Spec. Co., Inc., New York, N. Y.

CEMENT, IRON.
Smooth-On Mfg. Co., Jersey City, N. J.
Strong Mach. & Supply Co., N. Y.

CHAINS, DRIVE.
Jeffrey Mfg. Co., The, Columbus, Ohio.
Link-Belt Co., Chicago, Ill.

CHAIN WHEELS.
Babbitt Steam Specialty Co., New Bedford, Mass.

CHIMNEYS.
American Chimney Corp., N. Y.

CLAMSHELLS.
Williams Co., G. H., Erie, Pa.

CLEANERS, BOILER TUBE.
General Specialty Co., Buffalo.
Huyette Co., Inc., The Paul B., Philadelphia, Pa.
Lagonda Mfg. Co., Springfield, O.
Liberty Mfg. Co., Pittsburgh, Pa.
Pierce Co., The Wm. B., Buffalo, N. Y.
Pilley Pkg. & Flue Brush Mfg. Co., St. Louis, Mo.
Roto Co., The, Hartford, Conn.
Scully Steel & Iron Co., Chicago.
Self Cleaning Strainer Co., Chicago, Ill.

COAL AND ASH HANDLING MACHINERY.
Brown Hoisting Machinery Co., The, Cleveland, Ohio.
Conveyors Corp. of Amer., Chicago.
Detrick Co., M. H., Chicago.
Green Engineering Co., E. Chicago, Ind.
Jeffrey Mfg. Co., The, Columbus, Ohio.
Link-Belt Co., Chicago, Ill.
McMyler-Interstate Co., The, Cleveland, Ohio.
Portable Machinery Co., Passaic, N. J.
Stephens-Adamson Mfg. Co., Aurora, Ill.
Webster Mfg. Co., The, Chicago, Ill.

COAL CRUSHERS.
Brown Hoisting Machinery Co., The, Cleveland, Ohio.
Fuller-Lehigh Co., Fullerton, Pa.
Jeffrey Mfg. Co., The, Columbus, Ohio.
Pennsylvania Crusher Co., Philadelphia, Pa.
Stephens-Adamson Mfg. Co., Aurora, Ill.
Webster Mfg. Co., The, Chicago, Ill.

COAL STORAGE EQUIPMENT.
Brown Hoisting Machinery Co., The, Cleveland, Ohio.
Jeffrey Mfg. Co., The, Columbus, Ohio.
Link-Belt Co., Chicago, Ill.
Stephens-Adamson Mfg. Co., Aurora, Ill.
Webster Mfg. Co., The, Chicago.

COAL WEIGHING & MEASURING EQUIPMENT.
Webster Mfg. Co., The, Chicago.

COCKS, AIR AND STEAM.
Dart Mfg. Co., E. M., Providence, R. I.
Powell Co., The Wm., Cincinnati, Ohio.
Williams Valve Co., D. T., Cincinnati, Ohio.

COCKS, BLOWOFF.
Scully Steel & Iron Co., Chicago.

COILS AND BENDS.
Badger & Sons Co., E. B., Boston, Mass.

COMBUSTION APPLIANCES.
Bacharach Ind. Instrument Co., Pittsburgh, Pa.
Hays Corp., Jos. W., Michigan City, Ind.

COMBUSTION (CO_2) RECORDERS.
Bacharach Ind. Instrument Co., Pittsburgh, Pa.
Defender Auto. Regulator Co., St. Louis, Mo.
Foxboro Co., Inc., Foxboro, Mass.
Hays Corp., Jos. W., Michigan City, Ind.